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PERFORMANCE OF MELON (*CUCUMIS MELO* L.) HYBRIDS ACROSS DIVERSE ENVIRONMENTAL CONDITIONS

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SUMMARY

In interaction with the environment, the melon (*Cucumis melo* L.) hybrids had a wide phenotypic performance regarding growth, morphology, and yield-related parameters. The appraisal of melon genotypes in the targeted environments through multi-environment trials (MET) depended on phenotypic performance. The objectives of the presented study were to evaluate the performance of melon hybrids obtained from full-diallel crosses under three different environmental conditions. The study ran from November 2022 to February 2023 at three locations (Pandaan, Karangploso, and Pujon), with varying altitudes in East Java (Indonesia). The breeding material comprised 38 selected hybrids (out of 90 diallel hybrids), with 10 parents and two commercial check cultivars (Madesta and Glamour), sustained evaluation in a randomized complete block design (RCBD) with three replications at each location. Observations made on several yield characteristics of the fruit included weight, diameter, length, flesh thickness, and sweetness. At the Pandaan location, the melon hybrid H 18 performed better for fruit weight, length, and flesh thickness, and the hybrid H 19 for fruit diameter and sweetness than the melon's check cultivars. In Karangploso location, the hybrid H 10 for fruit weight and diameter, H 34 for fruit length, and H 12 for fruit sweetness outperformed the melon commercial cultivars. At the Pujon location, the hybrid H 34 for fruit weight, diameter, and length, H 6 for fruit flesh thickness, and the hybrid H 32 for fruit sweetness outperformed the check cultivars. Overall, the leading performance across all the test environments appeared with melon hybrid H 15 for fruit weight and length, and H 19 for fruit diameter, flesh thickness, and sweetness.

Keywords: Melon, *Cucumis melo* L., genotypes, diallel hybrids, multi-environment trials, phenotypic performance, fruit yield and quality traits

Key findings: Diverse test environments influenced the performance of melon hybrids. The hybrid H 15 and H 19 were promising for yield and quality-related traits at all three locations.

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INTRODUCTION

Melon (*Cucumis melo* L.), belonging to the family Cucurbitaceae and genus *Cucumis*, which consists of 38 species, is one of the most valuable commercial crops worldwide. The accurate origin of melons is unknown; however, some studies have suggested that melons originated in Africa and the hot valleys of Southwest Asia, especially Iran, Pakistan, and India (Malik, 2012). It is a belief that ancient Egyptians were the first to grow melons.

The melon-breeding program has three main objectives, i.e., increasing yield, improving fruit quality, and enhancing resistance against insect pests and diseases. Superior characteristics of melon include fruit weight with an average of >1.5 kg, fruit sweetness (12–15 °Brix), net density (>85%), and tolerance to pests and diseases.

Melon cultivation requires optimum temperatures between 27 °C and 30 °C. The fruit maturation process can better proceed with low humidity and water content for improved melon sugar content, texture, and flavor. A higher average temperature causes an increase in the rate of plant development and fruit maturation, but the fruit size may not reach the maximum. In addition, high humidity in the area of cultivation can cause melon plants to be susceptible to various pests and diseases (Virtuoso *et al*., 2022).

The melon performance is fragile to environmental variations. The phenotypic performance of the melon plant characteristics has considerable influences from several main factors, i.e., genotype (G), environment (E), and genotype and environment interaction (GEI). The environmental effects include varied elevations, temperatures, humidity, and soil type. Knowledge about GEI is advantageous for plant breeders to develop superior genotypes for all environmental conditions and specific locations. The genotype-by-environment interactions mainly cause differences in genotype performances. The selection of a suitable environment for a genotype is the final phase of plant breeding because the evaluation through genotype by environment interaction effects can maximize the gain from the selection (Yan *et al*., 2011). In the melon-breeding program, developing a cultivar adapted to various environments is the key objective (El-Soda *et al*., 2015).

Evaluating melon genotypes in several environments could remarkably identify desirable genotypes that can broadly adapt to various targeted environments (Dia *et al*., 2016). Genotype evaluation in the targeted environment depends on the phenotypic performance in the multi-environment trials (MET) (Oliovoto *et al*., 2019). The MET data visualization techniques have helped evaluate the environments and their ability to discriminate the genotype tests and visualize the performance ranking for selecting superior genotypes (Luo *et al.,* 2015). The targeted environments can considerably affect productivity and quality; therefore, such information is often helpful regarding the performance of genotypes in a specific environment. Hence, the latest study aimed to evaluate the performance of melon's 38 selected hybrids (out of 90 diallel hybrids) under three different environmental conditions.

MATERIALS AND METHODS

The presented study began in November 2022 until February 2023 at three locations based on different altitudes in East Java, Indonesia. The locations used were (i) Pandaan (203 masl; temperatures at 25 °C–32 °C; humidity 78%), (ii) Karangploso (720 masl; temperatures at 24 °C–30 °C; humidity 88%), and (iii) Pujon (1200 masl; temperatures at 15 °C–22 °C; humidity 90%). In this experiment, evaluating the 38 selected melon hybrids (out of 90 diallel hybrids) continued with 10 parents and two commercial check cultivars, i.e., Madesta and Glamour (Handayani *et al*., 2022).

Experimental procedure

The experiment proceeded in a randomized complete block design (RCBD) with three replications at each location. There were six plants in each genotype, and one polybag (40 cm) consisted of one plant. Polybags had a 0.5 m distance arrangement. The NPK (16:16:16) fertilizer application was 10 g per plant at 14, 21, 28, and 35 days after planting (DAP). Applying the KNO_3 fertilizer was 49 days after planting. Insect pest and disease control employed chemical insecticides (emamectin benzoate) and fungicides (29% simoxanil and 22.5% famoxadone; mancozeb; 70% propineb). The control of insects used the insecticides *Bemisia tabaci* Gennadius, *Liriomyza sativae* Blanch, and *Tetranychus* spp. The fungicide uses controlled *Pseudoperonospora cubensis* and *Podosphaera xanthii* Schlecht.

Phenotypic performance characterization

Observations on the fruit's several yield characteristics included the fruit weight, diameter, length, flesh thickness, and sweetness. Acquiring fruit weight had the melons from each experimental plot weighed using a digital scale. Fruit diameter measured at the center of the melon fruit used a vernier caliper, with the fruit length obtained by measuring the length of the melon from the base to the tip of the fruit with a ruler. The fruit flesh thickness measurement used a vernier caliper for the melon flesh thickness. Obtaining fruit sweetness utilized a brix refractometer.

Data analysis

The recorded data analysis used analysis of variance (ANOVA) based on RCBD, with the combined ANOVA also performed by following Gomez and Gomez (1984) and using the STAR software. Significant differences' determination used the Least Significant Increase (LSI) model with the following formula:

$$LSI = t\alpha \sqrt{\frac{2\ x\ mean\ square\ of\ error}{r}}$$

Where:
t_α is the t-student value at α degree of freedom from the mean square of error, and
r is replication numbers.

RESULTS

Analysis of variance

The analysis of variance of 38 selected hybrids (out of 90 diallel hybrids) and two commercial check cultivars for the fruit yield and quality characteristics of melons in each separate location appears in Table 1. Genotypes revealed significant ($P \leq 0.01$) differences for all five-fruit yield and quality traits of melon at two locations, i.e*.,* Pandaan and Pujon. At the third location, Karangploso, the genotypes enunciated significant ($P \leq 0.01$) differences for three traits, viz., fruit diameter, length, and flesh thickness, but nonsignificant for the melon's fruit weight and sweetness.

Combined analysis of variance

The combined analysis of the variance of 40 melon genotypes (comprising 38 hybrids and two commercial check cultivars) with combined three locations is available in Table 2. In combined ANOVA, the genotypes and genotype x environment interactions revealed significant ($P \leq 0.01$) variations for all five-fruit yield and quality traits of melon at three locations. Environmental main effects also significantly ($P \leq 0.01$) differed for the four yield and quality traits, fruit diameter, length, flesh thickness, and sweetness, but were nonsignificant for fruit weight.

Genetic variability and phenotypic performance

Fruit weight

The melon hybrid populations and check cultivars' mean values for fruit weight at different test locations are in Table 3. At the Pandaan location, the fruits of melon hybrid H 6, H 13, H 16, and H 26 occurred larger and heavier than fruits of check cultivar Madesta, and the fruits of hybrid H 9, H 15, H 18, H 19, H 21, and H 38 were heavier than fruits of both the check cultivars Madesta and Glamour. In

Table 1. Analysis of variance of hybrid populations and check cultivars for melon fruit yield and quality traits at three locations.

Characteristics	Locations		
	Pandaan	Karangploso	Pujon
Fruit weight	86419.53**	15898.82^{NS}	88019.23**
Fruit diameter	1.83**	1.51**	2.09**
Fruit length	3.31**	1.25**	3.60**
Fruit flesh thickness	25.08**	9.4**	20.3**
Fruit sweetness	4.88**	0.9^{NS}	2.94**

*, ** Significant at the 5% and 1% probability levels, respectively, NS: Non-significant.

Table 2. Combined analysis of variance of hybrid populations and check cultivars for melon fruit yield and quality traits at three locations.

Characteristics	E	G	G x E	Error	C.V. (%)
Fruit weight	90599.48^{NS}	78186.02**	56075.78**	24440.63	20.5
Fruit diameter	29.83*	2.23**	1.6**	0.61	6.95
Fruit length	15.57*	4.27**	1.94**	0.82	8.41
Fruit flesh thickness	165.89*	30.75**	12.01*	8.02	12.36
Fruit sweetness	121.48**	2.96**	2.88**	1.05	11.06

*, ** Significant at the 5% and 1% probability levels, respectively, NS: Non-significant, E = Environment, G = Genotype, G x E = Genotype by environment interaction, C.V. = Coefficient variation.

Table 3. Mean performance of melon hybrids in comparison with check cultivars for fruit weight at three locations.

Melon genotypes	Locations			Means (g)
	Pandaan (g)	Karangploso (g)	Pujon (g)	
Hybrid populations				
H-1	708.67	765.33	647.00	707.00
H-2	767.67	706.18	814.67	762.84
H-3	783.33	726.28	822.67	777.43
H-4	771.67	844.75 a	753.50	789.97
H-5	567.67	860.33 a	548.36	658.79
H-6	910.67 a	767.42	893.50 a	857.19 a
H-7	528.67	754.78	450.67	578.04
H-8	557.67	856.47 a	584.33	666.16
H-9	1054.67 ab	768.78	868.50 a	897.32 a
H-10	840.67	938.95 a	635.39	805.00
H-11	810.00	765.25	404.00	659.75
H-12	785.67	835.43 a	518.17	713.09
H-13	955.00 a	876.65 a	671.00	834.22
H-14	734.17	740.07	842.00 a	772.08
H-15	1085.67 ab	841.95 a	1030.56 ab	986.06 ab
H-16	895.17 a	701.18	610.17	735.51
H-17	847.00	798.33	637.83	761.06
H-18	1267.33 ab	668.28	550.50	828.71
H-19	979.17 ab	833.02 a	890.56 a	900.91 a
H-20	596.00	694.78	735.00	675.26
H-21	986.33 ab	845.58 a	997.22 a	943.05 a
H-22	741.00	811.97 a	712.83	755.27
H-23	888.33	875.72 a	796.94	853.66 a
H-24	628.00	667.07	679.83	658.30

Table 3. (cont'd.)

Melon genotypes	Locations			Means (g)
	Pandaan (g)	Karangploso (g)	Pujon (g)	
Hybrid populations				
H-25	470.67	838.03 a	703.56	670.75
H-26	908.67 a	815.72 a	749.44	824.61
H-27	774.33	873.52	600.08	749.31
H-28	612.33	733.28	540.17	628.59
H-29	639.00	865.55 a	851.17 a	785.24
H-30	737.67	766.37	646.28	716.77
H-31	812.67	700.50	695.50	736.22
H-32	645.33	793.82	664.83	701.33
H-33	667.00	713.43	711.33	697.26
H-34	630.67	724.42	1285.67 ab	880.25 a
H-35	683.23	668.95	919.83 a	757.34
H-36	880.67	712.62	621.67	738.32
H-37	673.00	710.35	792.00	725.12
H-38	1034.33 ab	760.00	965.83 a	920.06 a
Check cultivars				
Madesta	656.00	630.42	604.83	630.42
Glamour	733.33	762.33	791.33	762.33
Means	781.23	775.35	730.97	762.51
$LSI_{0.05}$	235.64	178.95	219.00	210.75
C.V. (%)	22.19	16.98	22.04	20.50

Means followed by letters indicate significantly superior over check cultivars at $LSI_{0.05}$
LSI: least significant increase, C.V.: Coefficient of variation.

the Karangploso site, the fruits of hybrid H 4, H 5, H 8, H 10, H 12, H 13, H 15, H 19, H 21, H 22, H 23, H 25, H 26, H 27, and H 29 were heavier than the check cultivar Madesta's fruits. For the Pujon location, the fruits of hybrid populations H 6, H 9, H 14, H 19, H 21, H 29, H 35, and H 38 were larger and weightier than the fruits of Madesta check cultivar, with the fruits of hybrid H 15 and H 34 heavier than the fruits of check cultivars Madesta and Glamour. Based on the combined mean performance across three locations, the fruits of hybrid H 6, H 9, H 19, H 21, H 23, H 34, and H 38 were thicker than the fruits of check cultivar Madesta, and the hybrid H 15 fruits were bulkier than both check cultivars Madesta and Glamour fruits. Overall, the maximum mean fruit weight was evident for melon hybrid H 18 at the Pandaan, H 10 at the Karangploso, H 34 at the Pujon, and H 15 in all test locations.

Fruit diameter

The mean data of melon hybrid populations and check cultivars for fruit diameter at three test locations are visible in Table 4. At the Pandaan location, the melon hybrids H 2, H 4, H 9, H 10, H 16, H 17, H 35, H 36, and H 38 gave enhanced fruit diameter than fruits of check cultivar Madesta. However, fruits of hybrids H 3, H 6, H 13, H 15, H 18, H 19, H 21, H 23, H 26, and H 31 exhibited greater diameters than check cultivars Madesta and Glamour fruits. At the Karangploso area, the fruits of hybrid H 8, H 12, H 17, and H 25 provided increased diameters than the fruits of check cultivar Madesta, with the fruits of hybrid H 10 only having a diameter wider than the fruits of check cultivars Madesta and Glamour. For the Pujon location, the fruits of hybrids H 6, H 9, H 14, H 19, H 21, H 23, H 29, H 35, and H 37 performed better, with

Table 4. Mean performance of melon hybrids in comparison with check cultivars for fruit diameter at three locations.

Melon genotypes	Locations			Means (cm)
	Pandaan (cm)	Karangploso (cm)	Pujon (cm)	
Hybrid populations				
H-1	10.81	9.81	10.26	10.29
H-2	12.16 a	9.41	11.41	10.99
H-3	12.51 ab	9.53	11.15	11.06
H-4	12.12 a	9.61	11.03	10.92
H-5	10.98	10.12	9.98	10.36
H-6	13.07 ab	11.50	11.95 a	12.17 a
H-7	11.37	10.92	9.26	10.52
H-8	10.97	12.34 a	10.11	11.14
H-9	12.26 a	10.60	11.49 a	11.45
H-10	11.96 a	12.60 ab	10.48	11.68 a
H-11	11.40	10.30	8.92	10.21
H-12	11.16	11.79 a	10.00	10.98
H-13	12.84 ab	10.61	10.96	11.47
H-14	11.15	10.41	11.57 a	11.04
H-15	12.58 ab	10.93	12.45 ab	11.99 a
H-16	12.22 a	11.06	10.11	11.13
H-17	11.93 a	11.79 a	10.50	11.41
H-18	12.63 ab	10.22	10.05	10.97
H-19	13.49 ab	11.46	11.89 a	12.28 a
H-20	10.61	10.93	11.11	10.88
H-21	12.61 ab	11.35	12.00 a	11.99 a
H-22	11.44	10.78	10.77	11.00
H-23	12.90 ab	11.44	11.78 a	12.04 a
H-24	11.18	10.77	10.75	10.90
H-25	9.96	11.82 a	10.89	10.89
H-26	12.61 ab	10.69	11.21	11.50
H-27	11.63	11.21	10.71	11.18
H-28	11.46	10.53	10.10	10.70
H-29	11.56	11.04	11.58 a	11.39
H-30	11.69	10.45	10.87	11.00
H-31	12.58 ab	10.51	11.23	11.44
H-32	11.37	10.68	10.87	10.97
H-33	11.68	10.20	11.18	11.02
H-34	10.83	10.55	12.68 ab	11.35
H-35	11.82 a	10.41	12.01 a	11.41
H-36	12.03 a	11.08	10.59	11.24
H-37	10.73	10.76	11.46 a	10.98
H-38	12.00 a	11.39	12.38 ab	11.93 a
Check cultivars				
Madesta	10.73	10.55	10.37	10.55
Glamour	11.41	11.30	11.19	11.30
Means	11.76	10.83	10.98	11.19
$LSI_{0.05}$	0.96	1.12	1.08	1.05
C.V. (%)	6.01	7.64	7.23	6.95

Means followed by letters indicate significantly superior over check cultivars at $LSI_{0.05}$
LSI: least significant increase, C.V.: Coefficient of variation.

diameters greater than the fruits of check cultivar Madesta. Similarly, the fruits of hybrids H 15, H 34, and H 38 had wider diameters than the fruits of check cultivars Madesta and Glamour. Based on the combined mean across and on average, hybrids H 6, H 10, H 15, H 19, H 21, H 23, and H 38 had greater diameters than the fruit diameters of check cultivar Madesta at all three locations. However, the largest fruits were evident for hybrid H 19 at the Pandaan location, for H 10 at the Karangploso site, for H 34 at the Pujon area, and for hybrid H 19 in all test locations.

Fruit length

The melon hybrid populations and check cultivars' mean data for fruit length at the targeted locations occur in Table 5. At the Pandaan location, fruits of hybrids H 15, H 18, and H 19 had longer lengths than check cultivars Madesta and Glamour fruits. In the Karangploso site, the tested hybrids did not differ significantly from both check cultivars based on the LSI at a 5% probability level. At the Pujon location, hybrids H 15 and H 21 revealed extended fruit lengths than the check cultivar Madesta, and the fruits of hybrid H 34 were comparatively lengthier than fruits of check cultivars Madesta and Glamour. Based on the combined means across three locations, the hybrid H 34 attained longer fruits than the check cultivar Madesta, with the hybrid H 15 having a longer fruit than the check cultivars Madesta and Glamour. Overall, the maximum mean fruit length manifested for the hybrid H 18 at the Pandaan location, H 34 at the Karangploso and Pujon locations, and the hybrid H 15 at all test locations.

Fruit flesh thickness

The mean data of melon hybrid populations and check cultivars for fruit flesh thickness at three test locations appear in Table 6. At the Pandaan location, hybrid H 19 had greater fruit flesh thickness than the check cultivar Glamour, while hybrid H 18 had thicker fruit flesh than the check cultivars Madesta and Glamour. For the Pujon site, the hybrid H 6 has shown enhanced fruit flesh thickness than the check cultivar Madesta. At the Karangploso area, the melon hybrids and check cultivars revealed nonsignificant differences in fruit flesh thickness based on an LSI at a 5% probability level. Overall, the greater fruit flesh thickness was apparent for the hybrid H 18 at the Pandaan location, check cultivar Glamour at the Karangploso site, the hybrid H 6 at the Pujon area, and hybrid H 19 at all test locations.

Fruit sweetness

The melon hybrid populations and check cultivars' mean data for fruit sweetness, an essential fruit quality trait, at targeted locations are available in Table 7. At the Pandaan location, the fruits of hybrid H34 occurred sweeter than the fruits of the check cultivar Madesta; however, the fruits of hybrids H 6, H 9, H 15, H 18, H 19, H 22, H 23, H 26, H 28, H 37, and H 38 were extraordinarily sweeter than both the check cultivars Madesta and Glamour fruits. For the Karangploso site, hybrids H 12 and H 34 provided sweeter fruits than the check cultivar Madesta. In the Pujon area, the tested melon hybrid populations and check cultivars revealed nonsignificant differences based on an LSI at a 5% probability level. On average, the enhanced fruit sweetness was evident in the hybrid H 19 at all test locations, with the check cultivar Glamour at the Karangploso site and the hybrid H 32 at the Pujon location.

DISCUSSION

The melon hybrid populations, with significant differences at each location and, on average, overall targeted locations, authenticated that the genotypes had superior genetic variability and scope for further improvement in fruit yield and quality-related traits (Islam *et al*., 2020; Mohosina *et al*., 2020). These effects of genotypes, environmental factors, and genotype and environment interaction are crucially necessary for breeders to facilitate the identification and selection process of promising genotypes.

Table 5. Mean performance of melon hybrids in comparison with check cultivars for fruit length at three locations.

Melon genotypes	Locations			Means (cm)
	Pandaan (cm)	Karangploso (cm)	Pujon (cm)	
Hybrid populations				
H-1	11.00	10.80	11.08	10.96
H-2	11.33	10.73	11.47	11.18
H-3	11.17	10.10	12.00	11.09
H-4	11.67	11.03	10.65	11.12
H-5	10.33	10.23	9.93	10.16
H-6	11.50	9.85	11.39	10.91
H-7	10.67	10.57	9.67	10.30
H-8	10.67	10.55	10.50	10.57
H-9	10.67	10.73	11.33	10.91
H-10	10.50	11.05	9.96	10.50
H-11	12.00	10.23	8.50	10.24
H-12	10.00	10.43	9.25	9.89
H-13	9.67	10.68	10.04	10.13
H-14	11.33	11.40	11.50	11.41
H-15	13.83 ab	11.95	12.83 a	12.87 ab
H-16	11.17	11.28	9.75	10.73
H-17	12.00	10.18	10.83	11.01
H-18	14.00 ab	10.30	9.83	11.38
H-19	13.33 ab	10.00	11.39	11.57
H-20	11.67	10.12	10.19	10.66
H-21	12.00	10.88	12.50 a	11.79
H-22	11.00	10.13	11.08	10.74
H-23	11.33	10.55	10.53	10.80
H-24	10.33	9.98	10.33	10.22
H-25	9.50	9.52	10.19	9.74
H-26	12.67	10.13	10.89	11.23
H-27	12.17	9.50	9.00	10.22
H-28	9.50	9.23	9.56	9.43
H-29	10.33	9.53	11.50	10.46
H-30	11.00	9.93	10.22	10.39
H-31	11.17	9.63	10.44	10.41
H-32	10.00	10.33	10.21	10.18
H-33	10.00	9.82	10.83	10.22
H-34	11.17	11.98	14.50 ab	12.55 a
H-35	10.50	10.77	11.67	10.98
H-36	10.83	10.38	9.83	10.35
H-37	10.33	10.45	10.83	10.54
H-38	10.83	10.13	11.25	10.74
Check cultivars				
Madesta	11.67	11.13	10.58	11.13
Glamour	11.67	11.58	11.50	11.58
Means	11.16	10.45	10.74	10.78
$LSI_{0.05}$	1.26	0.97	1.42	1.22
C.V. (%)	8.33	6.85	9.73	8.41

Means followed by letters indicate significantly superior over check cultivars at $LSI_{0.05}$
LSI: least significant increase, C.V.: Coefficient of variation.

Table 6. Mean performance of melon hybrids in comparison with check cultivars for fruit flesh thickness at three locations.

Melon genotypes	Locations			Means (mm)
	Pandaan (mm)	Karangploso (mm)	Pujon (mm)	
Hybrid populations				
H-1	19.23	19.28	19.88	19.46
H-2	22.93	20.05	22.33	21.77
H-3	24.48	19.70	23.18	22.46
H-4	21.73	19.95	23.59	21.76
H-5	19.77	19.52	19.88	19.72
H-6	24.83	21.60	28.37 a	24.94
H-7	18.57	21.02	20.00	19.86
H-8	22.77	20.32	21.90	21.66
H-9	24.80	20.08	22.28	22.39
H-10	21.07	21.22	21.62	21.30
H-11	26.07	19.62	16.77	20.82
H-12	21.13	23.45	22.75	22.44
H-13	23.77	22.08	21.03	22.29
H-14	22.20	22.15	21.33	21.89
H-15	26.88	23.25	27.30	25.81
H-16	25.78	24.47	21.88	24.04
H-17	24.10	21.67	21.95	22.57
H-18	31.07 ab	23.12	21.42	25.20
H-19	30.78 b	21.85	26.83	26.49
H-20	26.27	19.97	24.01	23.42
H-21	27.90	21.97	26.17	25.34
H-22	25.77	20.38	21.40	22.52
H-23	25.03	22.50	24.29	23.94
H-24	21.53	20.28	20.22	20.68
H-25	20.10	21.68	24.90	22.23
H-26	24.87	22.83	21.32	23.01
H-27	23.73	20.23	22.79	22.25
H-28	18.97	19.97	22.28	20.40
H-29	23.87	21.48	22.15	22.50
H-30	26.43	21.37	21.21	23.00
H-31	22.43	19.55	22.79	21.59
H-32	22.87	22.35	21.68	22.30
H-33	26.40	20.23	22.40	23.01
H-34	20.80	23.78	25.29	23.29
H-35	24.78	23.07	27.97	25.27
H-36	25.20	22.53	20.27	22.67
H-37	26.40	24.93	24.10	25.14
H-38	25.27	22.73	27.37	25.12
Check cultivars				
Madesta	26.60	25.65	24.70	25.65
Glamour	24.97	26.33	27.68	26.33
Means	24.05	21.71	22.98	22.91
$LSI_{0.05}$	3.00	4.71	3.64	3.82
C.V. (%)	10.18	14.41	11.65	12.36

Means followed by letters indicate significantly superior over check cultivars at $LSI_{0.05}$
LSI: least significant increase, C.V.: Coefficient of variation.

Table 7. Mean performance of melon hybrids in comparison with check cultivars for fruit sweetness at three locations.

Melon genotypes	Locations			Means (°Brix)
	Pandaan (°Brix)	Karangploso (°Brix)	Pujon (°Brix)	
Hybrid populations				
H-1	8.00	10.93	7.67	8.87
H-2	8.67	11.20	8.00	9.29
H-3	8.50	10.10	8.00	8.87
H-4	7.33	9.97	8.81	8.70
H-5	8.67	9.90	9.61	9.39
H-6	10.33 ab	9.90	8.22	9.49
H-7	7.83	10.10	7.67	8.53
H-8	8.67	10.75	7.33	8.92
H-9	9.50 ab	10.70	8.33	9.51
H-10	8.17	9.70	7.86	8.58
H-11	8.00	10.07	7.17	8.41
H-12	7.67	11.70 a	8.50	9.29
H-13	9.67	10.20	8.92	9.59
H-14	7.33	10.35	7.67	8.45
H-15	9.50 ab	10.43	8.50	9.48
H-16	7.67	10.27	8.00	8.64
H-17	7.33	10.35	7.83	8.51
H-18	11.33 ab	10.73	7.17	9.74
H-19	12.17 ab	10.23	9.17	10.52
H-20	7.67	10.43	8.00	8.70
H-21	8.33	9.27	8.00	8.53
H-22	9.67 ab	9.63	7.83	9.04
H-23	11.67 ab	9.77	9.17	10.20
H-24	8.33	9.57	9.17	9.02
H-25	8.33	10.27	10.33	9.64
H-26	9.67 ab	10.87	10.56	10.36
H-27	9.00	9.97	8.25	9.07
H-28	11.33 ab	10.93	8.61	10.29
H-29	7.67	10.30	9.56	9.17
H-30	7.67	10.17	7.83	8.56
H-31	8.67	10.47	8.44	9.19
H-32	7.67	11.00	10.75	9.81
H-33	8.17	10.43	8.33	8.98
H-34	9.17 a	11.60 a	8.11	9.63
H-35	7.67	11.13	7.83	8.88
H-36	7.67	11.37	9.33	9.46
H-37	10.33 ab	10.03	10.17	10.18
H-38	9.50 ab	10.53	8.00	9.34
Check cultivars				
Madesta	7.67	10.33	10.17	9.39
Glamour	8.00	10.67	10.67	9.78
Means	8.75	10.41	8.59	9.25
$LSI_{0.05}$	1.35	1.22	1.58	1.38
C.V. (%)	11.34	8.64	13.5	11.06

Means followed by letters indicate significantly superior over check cultivars at $LSI_{0.05}$
LSI: least significant increase, C.V.: Coefficient of variation.

The combined ANOVA reveals that the locations had significant differences for all the yield-related traits except for the fruit weight. A previous study also reported the same results, in which the environmental factors and genotype x environment interaction (GEI) effects exhibited significant differences in yield characteristics in melon (Lee *et al*., 2015; Sharma *et al*., 2020). Rad and Bakhshi (2020) also described that the GEI revealed notable variations in the total fruit number, marketable fruit yield, and total number of fruits per plant in melon genotypes. The genotypes and environments showed noteworthy differences through the combined analysis of variance for yield-related traits (Reddy *et al*., 2007; Adu *et al*., 2013).

The significant differences in environments indicated that the tested environmental conditions caused several results and better influenced the performance of melon genotypes. Differences in temperature and humidity in the test environments caused changes in the genotypes' performance. Daryono *et al*. (2014) reported that different locations substantially influenced melons' fruit yield and quality-related traits. Environmental factors indicate how the mean performance of melon genotypes differed among the environments. Altitude was also a vital factor that affected the genotypes' performance. In addition, several other factors could influence the performance of fruits, such as temperature (Hatfield and Prueger, 2015), light intensity (Körner, 2015), and the growth media conditions.

Genotypes played a significant role in managing the fruit yield and quality characteristics and revealed significant differences, indicating that the genotypes had diverse genetic makeup. The tested melon hybrid populations came from the crosses of several cultivars treated with varied pollination times and proportions of female and male flowers (Respatijarti *et al*., 2020). The processed performance of hybrids through isolation and selection of different potential inbred lines was successful for the hybridization with better prospects in the future (Handayani *et al*., 2022).

Based on the phenotypic performance of melon hybrids at the three tested locations, the hybrids performed excellently compared with commercial check cultivars, Madesta and Glamour, for fruit yield and quality-related traits. At the Pandaan location, the hybrid H 18 performed better for fruit weight, length, and flesh thickness, with the hybrid H 19 for fruit diameter and sweetness. In the Karangploso site, the hybrid H 10 showed remarkable performance for fruit weight and diameter, H 34 for fruit length, and the hybrid H 12 for fruit sweetness. At the Pujon area, the hybrid H 34 was superior for fruit weight, diameter, and length, H 6 for fruit flesh thickness, and the hybrid H 32 for fruit sweetness, performing better than other melon hybrid populations. In addition, melon populations performing best in all test environments were the hybrid H 15 for fruit weight and length and the hybrid H 19 for fruit diameter, flesh thickness, and sweetness.

The interaction effects of genotypes and environment significantly differed, indicating that the environmental factors had an influential role in the phenotypic performance of melon genotypes. The GEI effects caused inconsistency in genotype performance at different test locations. The GEI effects described the response of various genotypes to varying environmental conditions. Kocaturk *et al*. (2019) reported that GEI effects significantly differed among the genotypes for the recorded characteristics, indicating a notable variation in the genotypes' response to various environments, which caused a genotype to grow well under specific environmental conditions, but differently at the other location, as the growth and yield-related traits depended on the GE interaction influences.

In a previous study, the enhanced productivity through MET by using GEI information showed an increase of 40% (Kang, 2002). The best performance of a genotype in a specific environment or the most suitable environment can be further evaluated for the traits of interest (Sharma *et al*., 2020). Fruit weight described the net result of plant photosynthesis, and the increased fruit weight positively correlated to fruit diameter and length (Ullah *et al*., 2012). The genotype performance could incur influences from one or few genes and have effects from several genes' interactions combined with environmental outcomes. Such information is critical for understanding the behavior of the genotypes under varied ecological conditions (Kosev, 2014).

The melon fruit sweetness is one of the chief quality traits vital in marketing melons (Akrami and Arzani, 2019). The consumer preference for melon quality has sweetness, aroma, and texture determining it. Therefore, the sweetness of melons relates to the total soluble solid content. Sharma *et al*. (2020) reported that the total soluble solid content is an indicator that can be beneficial for breeders to select the melon germplasm associated with sweetness. In addition, soluble solid content accounts for more than 97% of the total dissolved solids in ripe melons (Li *et al*., 2006). Based on the USDA standard, good-quality melons must have 9–11 °Brix (Kultur *et al*., 2001).

CONCLUSIONS

In conclusion, the melon hybrids revealed varied performance compared with commercial check cultivars across three locations. The melon hybrids exhibiting the best performances were the hybrids H 18 and H 19 at the Pandaan location, H 10, H 12, and H 34 at the Karangploso site, and the hybrids H 6, H 32, and H 34 at the Pujon area. Overall, the melon hybrid H 15 and H 19 performed best for fruit yield and quality-related traits in all test environments.

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REFERENCES

Adu GB, Akromah R, Abdulai MS, Obeng-Antwi K, Kena AW, Tengan KML, Alidu H (2013). Assessment of genotype by environment interactions and grain yield performance of extra-early maize (*Zea mays* L.) hybrids. *J. Biol. Agric. Healtcare* 3(12): 7-15.

Akrami M, Arzani A (2019). Inheritance of fruit yield and quality in melon (*Cucumis melo* L.) grown under field salinity stress. *Sci. Rep*. 9: 1-13.

Daryono BS, Hadi R, Sidiq Y, Maryanto SD (2014). Phenotypic characters stability of melodi gama-3 melon (*Cucumis melo* L.) cultivar in rainy season based on multilocation test. *J. Proc. Series*. 1: 550-554.

Dia M, Wehner TC, Hassel R, Price DS, Boyhan GE, Olson S, King S, Davis AR, Tolla GE, Bernier J, Juarez B (2016). Value of locations for representing mega-environments and for discriminating yield of watermelon in the U.S. *Crop Sci*. 56: 1726-1735.

El-Soda M, Kruijer W, Malosetti M, Koorneef M, Aarts MGM (2015). Quantitative trait loci and candidate genes underlying genotype by environment interaction in the response of *Arabidopsis thaliana* to drought. *Plant Cell Environ*. 38: 585-599.

Gomez KA, Gomez AA (1984). Statistical Procedures for Agricultural Research. John Wiley and Sons, New York, USA.

Handayani DR, Ashari S, Adiredjo AL, Ardiarini NR, Roviq M (2022). Heterosis and combining ability of melon genotypes (*Cucumis melo* L.) for yield characters in full dialell crosses. *Bulg. J. Agric. Sci*. 28: 810-821.

Hatfield JL, Prueger JH (2015). Temperature extremes: Effect on plant growth and development. *Weather Clim. Extrem*. 10: 4-10.

Islam SS, Anothai J, Nualsri C, Soonsuwon W (2020). Analysis of genotype-environment interaction and yield stability of Thai upland rice (*Oryza sativa* L.) genotypes using AMMI model. *Aust. J. Crop Sci*. 14: 362-370.

Kang MS (2002). Quantitative Genetics, Genomics, and Plant Breeding. New York, NY: CABI.

Kocaturk M, Cubukcu P, Goksoy AT, Sincik M, Ilker E, Kadiroglu A, Vurarak Y, Sahin Y, Karakus M, Yildirim UA (2019). GGE biplot analysis of genotype x environment interaction in soybean grown as a second crop. *Turk. J. Field Crops*. 24(2): 145-154.

Körner C (2015). Paradigm shift in plant growth control. *Curr. Opin. Plant Biol*. 25: 107-114.

Kosev V (2014). Breeding and genetic assessment of some quantitative traits in crosses forage pea (*Pisum sativum* L.). *Open J. Genet*. 4(1): 22-29.

Kultur F, Harrison HC, Staub JE (2001). Spacing and genotype affect fruit sugar concentration, yield, and fruit size of muskmelon. *Hortic. Sci*. 36(2): 274-278.

Lee WJ, Lee JH, Jang KS, Choi YH (2015). Development of efficient screening methods for melon plants resistant to *Fusarium oxysporum* f. sp. melonis. *Korean J. Hortic. Sci. Tehnol*. 33(1): 70-82.

Li Z, Yao L, Yang Y, Li A (2006). Transgenic approach to improve quality traits of melon fruit. *Sci. Hortic*. 108(3): 268-277.

Luo J, Pan YB, Que Y, Zhang H, Grisham MP, Xu L (2015). Biplot evaluation of test environments and identification of mega-environment for sugarcane cultivars in China. *Sci. Rep*. 5: 15505. https://doi.org/10.1038/srep15505.

Malik A (2012). Analysis of genetic diversity of Indian melon (*Cucumis melo* L.) land races and its comparison with global reference melon population. Dissertation, Punjab Agricultural University, Punjab.

Mohosina F, Mehedi MNH, Mahmud E, Hasan MK, Noor MMA, Rahman MHS, Chowdhury AK (2020). Genetic diversity of commercially cultivated watermelon (*Citrullus lanatus*) hybrids in Bangladesh. *SABRAO J. Breed. Genet.* 52(4): 418–434.

Oliovoto T, Lucio ADC, Silva JAG da, Marchioro VS, Souza VQ de, Jost E (2019). Mean performance and stability in multi-environment trials. I: Combining features of AMMI and BLUP techniques. *Agron. J*. 111: 1-12.

Rad MRN, Bakhshi B (2020). GGE biplot tool to identify melon fruit weight stability under different drought conditions. *Int. J. Veg. Sci*. 27: 1-11.

Reddy ANK, Munshi AD, Behera TK, Sureja AK (2007). Correlation and path analyses for yield and biochemical characters in snapmelon (*Cucumis melo* var. *momordica*). *SABRAO J. Breed. Genet.* 39(1): 65-72.

Respatijarti, Adiredjo AL, Roviq M (2020). Influence of pollination time and flower proportion on the success rate of pollination and yield of melon varieties (*Cucumis melo* L.). *Asian J. Plant Sci*. 19: 469-473.

Sharma SP, Leskovar DI, Crosby KM, Ibrahim AMH (2020). GGE biplot analysis of genotype-by-environment interactions for melon fruit yield and quality traits. *HortSci*. 55(4): 533-542.

Ullah MZ, Hasan MJ, Chowdhury AZMKA, Saki AI, Rahman AHMA (2012). Genetic variability and correlation in exotic cucumber (*Cucumis sativus* L.) varieties. *Bangladesh J. Plant Breed. Genet*. 25(1): 17-23.

Virtuoso MCS, Valente TS, Silva EHC, Braz LT, Panizzi R de C, Vargas PF (2022). Implications of the inoculation method and environment in the selection of melon genotypes resistant to *Didymella bryoniae*. *Sci. Hortic*. 300: 1-7.

Yan W, Pageau D, Fregeau-Reid J, Durand J (2011). Assessing the representativeness and repeatability of test locations for genotype evaluation. *Crop Sci*. 51: 1603-1610.