RESEARCH ARTICLE

SABRAO Journal of Breeding and Genetics
57 (1) 13-24, 2025
http://doi.org/10.54910/sabrao2025.57.1.2
http://sabraojournal.org/
pISSN 1029-7073; eISSN 2224-8978

BREEDING BASED ON MULTI CRITERIA USING WEIGHT-BASED RANKING METHOD IN FORAGE WATERMELON

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SUMMARY

Important problems may appear in the selections made by considering more than one characteristic in plant breeding studies, which can have resolutions by increasing the weight of suitable characteristics in the selection. Within the scope of this study, it aimed to develop the Weight-Based Ranking Method (WBRM) to make decisions according to multicriteria in forage watermelon, which had no prior use in forage watermelon breeding studies. Forage watermelon seeds' sowing in viols in the greenhouse helped formed seedlings, later transplanted at 200 cm × 100 cm intervals in May 2017. An evaluation ensued according to the measurements and observations on the fruit rind color, shape of the fruit, the flesh color of the fruit, the number of fruits, fruit yield, rind thickness, Brix values in fruit, and seed yield. Significant differences were evident among the genotypes for the studied characteristics. The WBRM was successful for the selection of the most suitable fodder-type watermelon. In the WBRM, the score equivalents and percentages of the characteristics developed were within the scope of the study. The WBRM scores of the watermelon genotypes used in the study ranged from 108 to 714. The first 105 forage watermelon genotypes, with a total score of more than 500, gained selection for subsequent forage watermelon breeding studies. It was notable that the selection with the WBRM could be successfully beneficial in forage watermelon breeding and facilitate decision-making in selection.

Keywords: Breeding, forage watermelon, genotypes, selection, weight-based ranking

Key findings: It is difficult to select according to multicriteria in plant breeding. The WBRM technique and scores and percentages of characters used in selection, developed for the first time in forage watermelon breeding, was successful. Selection with the WBRM could be successful in forage watermelon breeding and facilitate decision-making in selection according to multicriteria.

Communicating Editor: Prof. Dr. Ijaz Rasool Noorka

Manuscript received: August 12, 2023; Accepted: August 16, 2024.

Citation: Tokat M, Acar R, Özköse A (2025).Breeding based on multi criteria using weight-based ranking method in forage watermelon. *SABRAO J. Breed. Genet.* 57(1): 13-24. http://doi.org/10.54910/sabrao2025.57.1.2.

INTRODUCTION

Forage watermelon (*Citrullus lanatus* var. *citroides*) is an annual herb belonging to the Cucurbitaceae family. The genus and species of fodder watermelon and edible (sweet) watermelon are the same, but the variety is different (Özköse and Acar, 2022). Forage watermelon could refer to the fodder melon, forage watermelon, horse watermelon, citron, citron melon, cow-melon, stock bowler, preserving melon, or tsamma melon (Laghetti and Hammer, 2007; Achigan-Dako *et al*., 2015; Levi *et al*., 2017; Santos *et al*., 2017; Shaik *et al*., 2017; Ngwepe *et al*., 2019; Ribeiro *et al*., 2022; Stephens, 2023). Some morphological differences are visible between fodder watermelons and sweet watermelons, especially for fruits (Özköse and Acar, 2022). In forage watermelons, the rind is hard, thick, and durable, the pulp is yellow-white or greenish, and the pulp is firm, retaining its juice for a long time (Acar *et al*., 2015), and the Brix content of the fruit is low (Özköse and Acar, 2022), with high pectin (Acar *et al*., 2019). The shape of the forage watermelon varies, from oval to cylindrical (Acar *et al*., 2019). The background (main color) of the fruit's outer rind is unlined and non-patterned or subtly patterned.

One of the most important features of forage watermelon is the storage life of the fruits. They need a long storage life because the consumption of watermelons produced as feeders takes a long time. Our previous studies determined forage watermelons can have storage of longer than one year under room conditions if without physical damages or injury. The purpose of growing watermelon forage in farm conditions as forage is to provide the juicy roughage required by animals during winter. For this reason, it will be sufficient to store the forage watermelon intact during the period from autumn to spring until fresh green fodder comes out in farm conditions in around six months. Researchers reported ripe fruits of forage watermelon can remain for more than six months without any rotting and significant losses of nutritional quality (Kavut *et al*., 2014).

Given a high unit area yield, it is a source of juicy forage, and crucially, a weight loss of 7.7%–15.0% in 210 days at room conditions occurs, unlike the edible watermelon (Geren *et al*., 2011; Simić *et al*., 2012). The fact that its longer storage without rotting makes the forage watermelon a good alternative roughage source. Forage watermelon is a one-year plant with the potential to easily enter the rotation system (Tokat *et al*., 2020). It is also suitable for agricultural mechanization. Although, studies conducted on forage watermelon are insufficient (Acar *et al*., 2012), studies on breeding, cultivating and storage of this plant, its use in animal feeding rations, and variety development are necessary because of its significant potential. Improved cultivars will be a requirement, especially for cultivation in more areas. Therefore, the aim of the presented study sought to examine the characteristics of forage watermelon populations obtained from different sources (different countries and regions) and select the genotypes superior for forage by selection breeding.

The selection study commenced in watermelon genotypes by using the data obtained in this study. The Single Selection Method used in foreign-pollinated plants became the basis in the selection process (Balkaya *et al*., 2008). The purpose of selection is to develop pure forage watermelon lines with long storage life, high fruit yield, and seed yield. Balkaya *et al*. (2009) used the WBRM for the breeding of pumpkin (*Cucurbita moschata* Duchesne), which is from the same family as watermelon, determining four superior pumpkin types. Within the scope of this study, it also aimed to develop the "Weight-Based Ranking Method" to select decision according to multicriteria in forage watermelon, which has not been functional before in forage watermelon breeding studies.

MATERIALS AND METHODS

This study commenced in the 2017 season (May-September) at Selçuk University, Faculty of Agriculture. The field where the trial materialized has a continental climate and the height of the sea level is approximately 1100 meters. Konya, the trial site, sits in the southern part of the Central Anatolian Region, where the continental climate is dominant. Winters are harsh, cold, and snowy, and summers are hot and dry. The total precipitation was 91.8 mm, the average temperature was 21.54 °C, and the relative humidity was 45.02% in the experimental months in 2017. Meanwhile, the long-term average total precipitation was 96.3 mm, the average temperature was 20.28 °C, and the relative humidity was 46.88%, showing a climate data very close to the trial year. According to the soil analysis, the soils of the field have clayey-loamy texture and alkaline characteristic (pH = 7.6), organic matter content = 1.08%, EC (µS cm^{-1}) = 190, P_2O_5 = 10.58 ppm, K_2O = 219.13 ppm, Na = 65.37 ppm, Ca = 5700 ppm, Zn = 2.79 ppm, and Fe = 2.22 ppm.

A total of 286 genotypes belonging to 32 populations obtained from different regions of Turkey and Turkmenistan served as the study material. The seeds of the supplied genotypes reached sowing in viols in the greenhouse at the beginning of April, creating seedlings. The field for the conduct of the study sustained plowing in autumn, with 30 kg of NPK (15-15-15) compound fertilizer applied per decare (0.1 ha) by mixing homogeneously with the soil. Then, raking the soil helped become ready for planting. The seedlings' planting in the hearths followed, with a 200 cm × 100 cm space on May 22, 2017. Then, maintenance operations, hoeing, weed control, hilling, and irrigation operations proceeded according to the development and needs of the plants. Nitrogen fertilizer application was at 5 kg da^{-1}, with pure substance calculation as the top fertilizer during the growing period (July 19). Harvest completion was on September 21, 2017.

Observations and measurements on vegetative characteristics progressed during the trial, and investigations and estimations on yield and fruit characteristics ensued after the fruits' harvest in autumn. Determining the characterization of the characteristics through observations considered the watermelon characterization criteria of UPOV (UPOV 2013) and TTSM (TTSM, 2017). The procedure applied for fruit (rind) color, the fruit's shape of the longitudinal section, the fruit's main flesh (inner layer) color, number of fruits per plant, fruit yield per plant and shell thickness, the water-soluble dry matter (Brix) content, and the seed yield.

The single plant selection (pure-line selection) method, used in open pollinated plants, was operational in the study. Male and female flowers exist at different places (monoecious) on the same plant in many of the watermelon genotypes (Zhang, 1998). For this reason, outcrossing is prevalent at a high rate (Wehner, 2011; Ngwepe *et al*., 2019). Inbreeding application helped obtain inbred homozygous lines (pure lines) of the selected types. Inbred seeds will serve in the production of selected genotypes in the selection's advanced stages.

Some characteristics needing emphasis in the selection of forage watermelon types and genotypes considered as forage watermelons reached validation. The essential ones from the observations and measurements associated with these characteristics became central in this study. The skin is hard, thick, and durable, the flesh is yellow-white or greenish, and the flesh is firm, retaining its juice for a long time after ripening in forage watermelons (Acar *et al*., 2015).

Water-soluble dry matter (Brix) amount of the fruit is low in forage watermelons, with a structure that does not break easily with its elastic structure and hard shell, and changes from oval to cylindrical (Acar *et al*., 2019). The background (main color) of the outer shell of the fruit is unlined and non-patterned or subtly patterned. Although, there may be types that are much better for feeding purposes than the previously mentioned ones. Relatedly, higher scores went to genotypes with fruit's external and main inner color (white and yellow), fruit with elliptical and cylindrical longitudinal cross-section, high fruit skin thickness, and low WSDM amount in fruit, based on authors' previous study results. Moreover, high fruit yield and seed yield are criteria in breeding for feed purposes.

The "Weighed Rating Method" employment determined the most suitable forage watermelon genotypes for selection. Selection criteria, classes, class, and relative scores developed were within the scope of this study because no previous use of WSDM as a selection method in forage watermelon ever existed. The characteristics used as selection criteria, their class scores, and relative scores are available in detail in Table 1. Total scores' determination proceeded by multiplying the class and relative scores of each genotype, earlier evaluated for characteristics emphasized during selection. In this respect, genotypes with scores above the average became the choices.

RESULTS AND DISCUSSION

The selection study initiated in watermelon genotypes used the data obtained in this study. The purpose of selection was to develop pure forage watermelon lines with long storage life, high fruit yield, and seed yield. This study applied weighting-based ranking method for the first time in forage watermelon breeding. Using the WBRM developed the score equivalents and percentages of the characteristics within the scope of the study. As mentioned above, the class scores and relative scores occur in Table 1. The class score of the genotype, evaluated for the characteristics emphasized, had its relative scores multiplied to determine the total scores (Tables 2 to 6). The total scores of the genotypes assessed in the study ranged between 108 and 714. The first 105 watermelon genotypes with a total score higher than 500 became options for subsequent forage watermelon breeding. The selection and inbreeding studies will continue for these genotypes. The researchers kept the number of selected genotypes a little high, and in the following years, they desired to continue with a wider genetic-based material based according to durability, yield, quality, and storage criteria. However, if the desire was to work with a superior and limited number of genotypes to serve in the next breeding works, it will be necessary to select the genotypes 279, 247, 173, 62, 67, 243, 29, 241, 245, and 249, with the highest total score (682 and higher total points).

Various fruit sizes, shapes, and colors are evident in *Citrullus* spp. (Achigan-Dako *et al*., 2015). Fruit shape is a distinctive characteristic of forage watermelons. For this reason, this characteristic's inclusion in the weighted rating occurred, with a relative score of 12. These classes received higher scores because feeder-type watermelons are generally oval, elliptic, broad elliptic, and elongated elliptic (Ngwepe *et al*., 2019; Acar *et al*., 2015). The background (main color) of the outer shell of the fruit is yellow-white, lightly unlined, and non-patterned, or subtly patterned (Özköse and Acar, 2022). The relative score of the fruit's outer color received an eight, and yellow, white, and green colors attained five, three, and two points, respectively, from high to low, as grade points.

Whether phenotypic differences between citron types with contrasting flesh colors (white–green vs. orange or yellow) (Levi *et al*., 2013; Ngwepe *et al*., 2019) are indicative of genetic differences at molecular level remains unknown (Ngwepe *et al*., 2019). However, in our previous studies, the flesh colors of forage watermelon types with a long storage period are typically green-white, white, or whitish yellow. The fruit's flesh color received a relative score of six, with the highest-grade points (five and four) given to these colors. Santos *et al*. (2017) stated the variation in the number of fruits per plant and fruit yield in forage watermelon is high, and although, the environment greatly affected it, genetic differences may have contributed to this variation. Since this study proceeded under the same environmental conditions, differences in fruit number per plant can be considerably an expression of genotypic structure. The relative score of the number of fruits per plant was eight.

The higher the number of fruits, the higher the class scores. Although the number of fruits per plant is an important criterion for yield, it is not sufficient alone because, in cases

Table 1. Developed weighted rating scores for fodder watermelon genotypes.

Characteristics	Descriptions	Grade scores	Relative Rating
Fruit: Shape of a longitudinal section	Circular	1	12
	Broad elliptic	2	
	Elliptic	4	
	Cylindrical	5	
Fruit: Background of skin	White	3	8
	Yellow	5	
	Green	2	
Fruit: The main color of flesh	White	5	6
	Yellow	4	
	Orange	2	
	Red	1	
	Purple	1	
Number of fruits per plant (pieces plant^{-1})	1	1	8
	2	2	
	3	3	
	4	5	
	5	7	
	≥6	7	
Fruit yield per plant (kg bitki^{-1})	≤ 4.9	1	16
	5.0 – 9.9	3	
	10.0 – 14.9	5	
	15.0 – 19.9	7	
	20.0 – 24.9	8	
	≥ 25.0	9	
Fruit: Thickness of the outer layer of the pericarp (mm)	0.0 – 9.9	1	20
	10.0 – 19.9	3	
	20.0 – 29.9	5	
	30.0 – 39.9	7	
	≥ 40.0	9	
The concentration of total soluble solids (Brix)	2	13	20
	3	11	
	4	9	
	5	7	
	6	5	
	7	3	
	8	1	
	9	1	
	10	1	
	11	1	
Seed yield (g fruit $^{-1}$)	0.0 – 19.9	1	10
	20.0 – 39.9	1	
	40.0 – 59.9	1	
	60.0 – 79.9	3	
	80.0 – 99.9	3	
	100.0 – 119.9	3	
	120.0 – 139.9	5	
	140.0 – 159.9	5	
	160.0 – 179.9	5	
	180.0 – 199.9	7	
	≥ 200	7	
Total			100

Table 2. Weighed rating scores of watermelon genotypes.

Genotype No.	SF	FC	CFF	NF	FY	TK	BRIX	SY	Total
279	60	16	24	40	144	140	220	70	714
247	60	40	24	24	128	140	220	70	706
173	60	40	30	56	144	100	220	50	700
62	60	40	24	24	112	140	220	70	690
67	60	40	24	24	112	140	220	70	690
243	60	40	24	24	112	140	220	70	690
29	24	40	24	40	128	180	180	70	686
241	60	40	24	16	112	140	220	70	682
245	60	40	24	40	128	100	220	70	682
249	60	40	24	16	112	100	260	70	682
242	60	40	24	56	128	100	220	50	678
276	60	40	24	24	128	100	220	70	666
251	60	40	30	40	144	100	220	30	664
71	24	16	24	24	144	140	220	70	662
180	60	40	24	40	128	60	260	50	662
118	60	16	30	40	144	100	220	50	660
60	60	40	30	24	112	100	220	70	656
69	60	40	30	24	112	100	220	70	656
278	24	16	24	16	144	140	220	70	654
154	24	16	30	24	128	140	220	70	652
56	60	40	24	24	112	100	220	70	650
238	60	40	30	16	112	140	220	30	648
254	60	40	30	16	112	140	180	70	648
9	60	16	24	24	112	140	220	50	646
177	60	40	24	24	128	100	220	50	646
178	60	40	24	24	128	100	220	50	646
275	24	40	24	16	112	140	220	70	646
281	24	16	24	24	128	140	220	70	646
283	48	40	24	40	144	140	180	30	646
244	60	40	30	24	80	100	260	50	644
237	60	40	12	16	80	140	220	70	638
206	24	16	30	24	128	140	220	50	632
120	48	16	30	56	128	140	180	30	628
5	60	16	24	16	112	100	220	70	618
156	24	16	24	56	128	180	180	10	618
68	24	16	30	24	128	100	220	70	612
117	60	16	30	24	112	100	220	50	612
58	60	40	24	24	112	100	220	30	610
239	60	40	24	24	112	60	220	70	610
200	24	16	24	24	128	140	220	30	606
2	60	16	30	16	112	100	220	50	604
4	60	16	24	40	112	100	220	30	602
14	60	40	24	24	80	100	220	50	598
72	24	16	24	40	144	100	180	70	598
179	60	40	24	16	48	100	260	50	598
101	12	16	30	40	128	140	180	50	596
246	60	40	30	8	48	100	260	50	596
73	24	16	12	24	144	140	180	50	590
155	24	16	30	16	112	100	220	70	588
252	60	40	30	8	80	100	220	50	588
59	60	40	30	24	80	100	220	30	584
253	60	40	24	8	80	100	220	50	582
186	24	16	6	40	144	140	180	30	580
202	24	16	30	56	144	100	180	30	580
248	60	24	30	16	80	100	220	50	580
277	12	40	30	40	128	100	220	10	580
70	48	16	30	24	128	100	180	50	576
104	12	24	30	56	144	100	180	30	576
153	24	16	24	56	144	100	180	30	574
7	60	16	30	8	48	180	180	50	572
63	60	16	30	16	80	60	260	50	572
282	24	16	30	24	128	100	220	30	572
66	24	16	30	40	128	140	140	50	568
57	60	40	30	16	48	100	220	50	564
122	24	16	30	56	128	100	180	30	564
1	48	16	30	16	80	100	220	50	560

SF: the shape of the longitudinal section of the fruit, FC: the ground color of the skin of the fruit, CFF: the main color of the flesh of the fruit, NF: the number of fruit per plant, FY: fruit yield per plant, TK: thickness of the outer layer of the pericarp of fruit, BRIX: water-soluble total dry matter in fruit, and SY: seed yield per fruit.

Table 3. Weighed rating scores of watermelon genotypes.

Genotype No	SF	FC	CFF	NF	FY	TK	BRIX	SY	Total
12	60	40	24	16	48	100	220	50	558
16	60	40	24	16	48	100	220	50	558
17	60	40	24	24	80	60	220	50	558
19	60	40	24	24	80	60	220	50	558
10	60	40	30	8	48	100	220	50	556
64	48	16	24	8	48	180	180	50	554
167	12	16	30	16	48	180	220	30	552
55	60	40	24	16	80	60	220	50	550
139	12	16	24	8	80	140	220	50	550
54	24	16	30	16	112	60	220	70	548
161	24	16	24	56	144	140	100	30	534
140	12	16	24	8	80	140	220	30	530
240	60	40	24	16	80	100	180	30	530
250	60	40	24	16	80	100	180	30	530
88	12	16	30	40	80	100	220	30	528
204	24	16	30	24	144	140	120	30	528
137	12	16	12	16	80	180	180	30	526
158	24	24	30	24	112	140	140	30	524
23	12	40	24	16	80	100	220	30	522
124	24	16	24	16	112	100	180	50	522
125	24	16	24	8	80	100	220	50	522
65	48	16	30	16	80	100	180	50	520
18	60	40	24	16	48	60	220	50	518
257	48	40	24	8	48	140	180	30	518
214	12	16	30	56	112	100	180	10	516
13	48	40	30	16	48	60	220	50	512
61	60	40	30	24	48	60	220	30	512
284	24	16	30	24	128	100	140	50	512
141	12	16	24	8	80	140	180	50	510
175	60	40	24	8	48	100	180	50	510
212	12	16	24	56	112	100	180	10	510
48	12	40	30	8	48	100	220	50	508
172	60	40	30	8	80	60	220	10	508
217	12	16	24	24	80	140	180	30	506
255	60	16	24	16	80	60	180	70	506
280	12	16	24	16	48	140	220	30	506
286	24	16	24	24	128	100	140	50	506
3	60	16	30	8	80	60	180	70	504
188	24	16	24	24	144	100	140	30	502
15	60	40	24	16	48	60	220	30	498
86	12	16	24	8	48	140	220	30	498
174	60	40	24	16	48	60	220	30	498
143	12	16	24	8	80	140	180	30	490
145	12	16	24	16	112	100	180	30	490
8	60	16	24	8	48	100	180	50	486
83	12	16	30	16	80	100	180	50	484
171	60	16	24	24	128	60	120	50	482
84	12	16	30	24	48	100	220	30	480
176	60	40	24	16	48	60	180	50	478
6	60	16	24	8	16	100	220	30	474
259	48	40	12	16	48	140	140	30	474
215	12	16	30	24	80	100	180	30	472
138	12	16	24	8	80	100	180	50	470
152	48	16	30	16	48	60	220	30	468
21	12	16	30	16	80	100	180	30	464
103	12	16	30	56	80	60	180	30	464
121	48	16	30	40	80	60	180	10	464
82	24	16	30	40	80	100	140	30	460
148	12	16	30	24	48	100	220	10	460
232	12	16	30	40	112	100	140	10	460
218	12	16	12	40	144	100	100	30	454
274	24	16	30	16	112	140	100	10	448
85	12	16	12	16	80	100	180	30	446
196	48	24	12	40	112	60	100	50	446
216	12	16	30	16	80	100	140	50	444
136	12	16	24	8	48	100	220	10	438
157	24	16	30	16	80	100	140	30	436
38	12	16	24	24	80	100	140	30	426
11	60	40	30	8	16	20	220	30	424

Table 4. Weighed rating scores of watermelon genotypes.

Genotype No.	SF	FC	CFF	NF	FY	TK	BRIX	SY	Total
285	12	16	30	24	48	100	140	50	420
24	12	16	24	16	80	100	140	30	418
43	12	16	24	16	80	140	100	30	418
89	12	16	24	24	112	60	140	30	418
144	12	16	24	8	48	100	180	30	418
22	48	16	24	8	48	100	140	30	414
142	12	16	24	8	80	100	140	30	410
126	48	16	24	16	48	100	140	10	402
228	48	40	12	24	48	20	180	30	402
198	48	40	12	24	80	60	100	30	394
170	12	16	30	16	48	60	180	30	392
41	12	16	24	24	80	60	140	30	386
39	12	16	30	16	80	60	140	30	384
42	12	16	30	24	48	100	140	10	380
44	12	40	12	16	48	100	100	50	378
213	12	16	12	16	48	100	140	30	374
169	12	16	30	16	48	60	180	10	372
210	12	16	30	16	48	100	140	10	372
45	12	40	12	8	48	100	100	50	370
263	48	40	12	40	80	60	20	70	370
92	12	16	30	40	80	100	60	30	368
37	12	16	24	8	16	140	140	10	366
164	12	16	12	8	48	140	100	30	366
211	12	16	24	24	80	100	100	10	366
223	48	40	12	16	80	100	20	50	366
28	12	16	24	8	112	60	100	30	362
98	12	16	24	56	80	60	100	10	358
193	48	40	24	16	80	60	60	30	358
194	12	40	12	16	48	60	140	30	358
219	12	16	24	16	80	100	100	10	358
52	12	40	30	16	48	20	180	10	356
258	48	40	12	16	48	60	100	30	354
25	12	16	30	16	48	60	140	30	352
51	12	40	24	24	80	60	60	50	350
199	48	24	24	16	48	60	100	30	350
221	48	24	24	24	80	60	60	30	350
27	12	16	24	16	48	60	140	30	346
209	12	16	30	24	48	100	100	10	340
119	48	16	24	24	16	60	140	10	338
222	48	40	12	16	48	20	100	50	334
87	12	16	30	8	16	60	180	10	332
166	12	16	30	8	16	60	180	10	332
168	12	16	30	8	16	60	180	10	332
264	48	24	12	16	80	60	60	30	330
99	12	16	24	56	48	60	100	10	326
181	12	16	24	16	48	60	140	10	326
226	48	24	12	24	48	60	60	50	326
91	12	16	12	24	48	100	100	10	322
220	48	40	12	24	48	60	60	30	322
114	60	16	6	40	128	20	20	30	320
49	12	40	12	16	48	60	100	30	318
195	12	40	12	16	48	60	100	30	318
35	12	24	24	16	48	60	100	30	314
197	48	40	12	8	16	60	100	30	314
20	12	16	30	8	16	60	140	30	312
40	12	16	30	16	48	60	100	30	312
113	48	40	6	16	48	60	60	30	308
123	12	16	30	24	16	60	140	10	308
26	12	16	24	16	48	60	100	30	306
46	12	16	12	16	80	60	60	50	306
50	12	24	24	8	48	60	100	30	306
105	12	16	24	16	48	100	80	10	306
224	48	40	12	16	80	60	20	30	306
149	48	16	6	8	16	100	100	10	304
106	12	16	30	16	16	60	140	10	300
201	12	16	30	16	16	20	180	10	300
31	12	16	24	8	48	60	100	30	298
93	12	16	12	40	48	60	100	10	298
133	12	16	12	40	48	60	100	10	298

Table 5. Weighed rating scores of watermelon genotypes.

Genotype No.	SF	FC	CFF	NF	FY	TK	BRIX	SY	Total
227	48	24	12	24	80	60	20	30	298
79	12	16	12	16	48	20	140	30	294
165	12	16	30	16	48	60	100	10	292
132	12	16	12	24	48	60	100	10	282
160	24	16	24	24	80	60	20	30	278
163	12	16	12	16	48	100	60	10	274
256	48	40	12	8	16	60	60	30	274
116	12	40	6	16	48	60	60	30	272
131	12	16	12	40	80	60	20	30	270
184	24	16	24	8	48	100	20	30	270
225	48	24	24	8	16	60	60	30	270
207	12	16	6	8	16	100	100	10	268
32	12	16	24	16	48	60	60	30	266
162	12	16	24	16	48	60	60	30	266
150	48	16	6	8	16	100	60	10	264
47	12	24	12	8	16	60	100	30	262
159	12	16	30	24	48	60	60	10	260
261	48	24	12	16	48	60	20	30	258
96	12	16	12	24	80	60	20	30	254
262	48	24	6	16	48	60	20	30	252
203	12	16	6	8	16	60	120	10	248
97	12	16	24	56	48	60	20	10	246
107	12	16	24	8	16	100	60	10	246
185	12	16	24	8	16	100	60	10	246
234	12	16	12	16	80	60	20	30	246
108	48	24	6	8	48	60	20	30	244
112	48	16	6	16	48	60	20	30	244
33	12	24	24	16	16	60	60	30	242
134	12	16	12	24	48	60	60	10	242
135	12	16	12	16	16	20	140	10	242
190	24	16	12	16	80	60	20	10	238
233	12	16	24	16	80	60	20	10	238
109	48	16	6	8	48	60	20	30	236
30	12	24	24	16	48	60	20	30	234
36	12	24	24	8	16	60	60	30	234
53	12	24	24	8	16	60	60	30	234
182	12	16	12	16	48	60	60	10	234
192	12	24	24	8	16	60	60	30	234
229	12	16	12	16	48	60	60	10	234
100	12	16	6	16	48	60	60	10	228
102	12	16	6	8	16	60	100	10	228
189	12	16	6	16	48	60	60	10	228
191	24	16	12	8	48	60	20	30	218
75	12	16	12	16	48	60	20	30	214
77	12	16	12	16	48	60	20	30	214
260	48	40	12	8	16	20	60	10	214
268	12	16	12	16	48	60	20	30	214
205	12	16	6	8	16	60	60	30	208
265	12	16	24	8	16	100	20	10	206
269	12	16	24	16	48	60	20	10	206
151	48	16	6	8	16	60	20	30	204
94	12	16	12	16	48	60	20	10	194
127	12	16	12	8	16	60	60	10	194
183	12	16	12	8	16	60	60	10	194
230	12	16	12	16	48	60	20	10	194
231	12	16	12	16	48	60	20	10	194
235	12	16	12	16	48	60	20	10	194
266	12	16	12	8	16	60	60	10	194
267	12	16	12	16	48	60	20	10	194
34	12	24	12	16	16	60	20	30	190
208	12	16	6	8	16	60	60	10	188
76	12	16	12	8	16	60	20	30	174
78	12	16	12	8	16	60	20	30	174
81	12	16	12	16	48	20	20	30	174
236	12	16	12	8	16	60	20	30	174
128	12	16	12	24	16	60	20	10	170
111	12	16	6	8	16	60	20	30	168
90	12	16	12	16	16	60	20	10	162
95	12	16	12	16	16	60	20	10	162

Table 6. Weighed rating scores of watermelon genotypes.

Genotype No.	SF	FC	CFF	NF	FY	TK	BRIX	SY	Total
110	24	16	6	8	16	60	20	10	160
80	12	16	12	8	16	60	20	10	154
130	12	16	12	8	16	60	20	10	154
187	12	16	12	8	16	60	20	10	154
270	12	16	12	8	16	60	20	10	154
272	12	16	12	8	16	60	20	10	154
115	12	16	6	16	48	20	20	10	148
147	12	16	6	8	16	60	20	10	148
74	12	16	12	8	16	20	20	10	114
129	12	16	12	8	16	20	20	10	114
271	12	16	12	8	16	20	20	10	114
273	12	16	12	8	16	20	20	10	114
146	12	16	6	8	16	20	20	10	108

where the plant cannot grow more fruits, it may not give the desired yield. Ribeiro *et al*. (2022) reported the number of fruits per plant had a negative correlation with fruit weight, and plants producing more fruits would have lower fruit weights, as a result of more assimilates and nutrient distribution. For this reason, more importantly, considering yield per plant was vital, with a relative score of 16. The higher the yield per plant, the higher the class score. Fruits with a greater rind thickness can have longer storage because they are more resistant to impact and deterioration (Santos *et al*., 2017).

Fruit skin thickness is crucial for feeder types, with a positive effect on storage times. Consequently, the relative score remained high, increasing the class score as the shell thickness increased. It was evident in the study that the rate of Brix (flesh soluble solids content) was high in edible types and low in feed types (Tokat *et al*., 2020), which positively affected the storage life. The Brix relative score in fruit is 20, and the genotypes with low Brix rates received high scores. The seed yield relative score is 10, with the class score increased depending on the boosted seed yield. Watermelon seeds can serve as a food source for livestock. Acar *et al*. (2015) stated the contribution of the seed to the nutritional value of the fruit of the forage watermelon (as crude protein, crude oil, NDF and ADF) is positive. However, since there are watermelon types for edible use and have a short storage period in the presented study, both the relative score and the class score for seed yield remained moderate. However, if all the genotypes studied were forage types, then a higher relative score and grade score could be appropriate for seed yield (Daryono *et al*., 2016; Adiredjo *et al*., 2024).

CONCLUSIONS

Critical problems may emerge in the selections made by considering more than one characteristic in plant breeding studies, which can have resolutions by increasing the weight of suitable characteristics in the selection. In the presented study, the purpose was to determine the vegetative and agricultural characteristics of watermelon genotypes obtained from different sources and develop a WBRM for the selection of genotypes to serve as feeds. As a result of this study, it revealed selection with the WBRM application could be successful in forage watermelon breeding and facilitate decision-making in selection.

ACKNOWLEDGMENTS

This article is part of Mehmet Tokat's Master's Thesis.

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