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Heterosis and inbreeding depression of F_2 segregating population for yield, quality and shelf-life characters in muskmelon

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Abstract
This study investigates the dynamics of inbreeding depression and heterosis in a population of F_2 muskmelon (*Cucumis melo* L.), focusing on various yield, quality, and shelf life traits. The research conducted at Dr. YSRHU-College of Horticulture, Anantharajupeta, explored traits such as fruit yield, quality and shelf life characteristics across 162 F_2 plants derived from the selfing of F_1 hybrids. Results suggest that traits like node of the first male flower emergence, titrable acidity and β-carotene suggesting they are primarily influenced by additive genetic effects, The study underscores the complexity of genetic interactions shaping muskmelon traits, offering insights for future breeding strategies aimed at enhancing yield, quality and shelf life traits.

Keywords: Muskmelon, inbreeding depression, heterosis, F_2 population, yield, quality, shelf life

Introduction

Muskmelon (*Cucumis melo* L.) is a vegetable crop within the Cucurbitaceae family, which comprises of approximately 118 genera and 825 species (Bailey and Bailey, 1976) [3]. Globally, vegetable production totals over 212.54 million metric tonnes from an area of 11.30 million hectares, with muskmelon contributing 14.98 million metric tonnes from 0.67 million hectares (NHB, 2022-23). Muskmelons are renowned for their juicy, delicious taste and are valued for their nutritional and medicinal properties. Muskmelon juice is recognized for being highly nutritious, diuretic, demulcent, and possessing aphrodisiac properties. Melon plants also contain various bioactive compounds such as elaterin, stigmasterol, β-sitosterol, and cucurbitacin, which are known for their anti-tumor properties (Duke and Ayensu, 1985) [6]. Each 100 grams of edible fruit provides approximately 17 to 26 calories of energy, 3.5 grams of carbohydrates, and 0.3 grams of protein, along with 32 mg of calcium, 1.4 mg of iron, and 14 mg of phosphorus (Chakrabarti, 2011) [5].

Heterosis breeding is widely acknowledged as a practical approach for enhancing yield and other economically important crop traits. Heterosis refers to the increased vigour observed in the F_1 hybrid compared to its parents (Hallauer *et al.* 2010) [8]. This vigour, also known as hybrid vigour, can manifest as higher productivity, uniformity, improved quality, inherent resistance to pests and diseases, adaptation to different environments, and early maturity. However, every hybridization does not result in hybrid vigour; it occurs selectively with specific parental combinations that produce heterotic progeny.

To effectively implement a heterosis breeding program in muskmelon, it is crucial to first understand the genetic basis and quantitative inheritance of traits (Pandey and Kumar 2006) [12]. Additionally, assessing the potential of parents in hybrid combinations to exhibit hybrid vigour (Pre-potency) is essential. This knowledge forms the foundation for selecting appropriate parent lines and optimizing hybrid combinations to achieve desired breeding goals in muskmelon cultivation. Apart from heterosis studies, understanding inbreeding depression is crucial in determining the appropriate breeding methodologies for crop improvement. Inbreeding depression occurs when unfavourable recessive genes become fixed in the F_2 population, leading to decreased vigour and fitness. This phenomenon underscores the importance of carefully managing genetic variability and selecting against deleterious alleles during breeding programs to maintain and enhance desirable crop traits. Inbreeding depression and heterosis are critical genetic phenomena influencing crop performance, with implications for breeding programs to improve productivity and fruit quality. This study delves into these genetic effects in the F_2 generation of muskmelon, focusing on yield per plant, fruit characteristics (Size, weight and firmness), biochemical composition (sugars, acids and vitamins) and shelf life.

Materials and Methods

The experiment was conducted at Dr. YSRHU-College of Horticulture, Anantharajupeta, Dr. Y.S.R. Horticultural University during the 2022-23 period. This location is situated in the southern agro-climatic zone of Andhra Pradesh, at coordinates 13°05' N latitude and 79°09' E longitude. F_2 seeds were derived through the selfing of the F_1 hybrid. The experimental setup included P_1, P_2, F_1, and a population of 162 F_2 plants, planted in a non-replicated manner. The F_2 plants were spaced one meter apart in both row and plant-to-plant, following standard cultural practices. Observations encompassing morphological, yield, and quality traits of muskmelon were recorded individually for all 162 F_2 plants. Statistical analysis was conducted to evaluate inbreeding depression and heterosis effects across these traits.

Results and Discussion

In the present study, heterosis is reported over mid-parent (Heterosis) and over better parent (Heterobeltiosis). Inbreeding depression is estimated over F_2 generation, and the results of the present study are discussed for the fruit yield, quality, and shelf life characteristics with respect to heterosis and inbreeding depression simultaneously.

For the trait node number at which the first male flower appears, the effects of heterosis, heterobeltiosis, and inbreeding were -43.98%, 0.14%, and -28.57%, respectively. For node number at which the first perfect flower appears, the observed effects were -36.14%, 0.00%, and 13.20%, respectively. For days to the first appearance of the male flower, the effects were -40.05%, -10.07%, and 5.63%, respectively. For days to the first appearance of the female flower, the effects were -40.73%, -8.74%, and 1.59%, respectively. Lastly, for sex ratio, the effects were -23.84%, 12.55%, and 7.63%, respectively.

For the node number of the first appearance of male flowers, significant effects were observed: a decrease of 43.98 due to heterosis, an increase of 0.14 due to heterobeltiosis, and a reduction of 28.57 due to inbreeding. For the node number of the first appearance of perfect flowers, the effects were a decrease of 36.14 (heterosis), no change (Heterobeltiosis), and an increase of 13.20% (Inbreeding). Regarding the timing of flower appearances, heterosis showed decreases of 40.05 for male flowers and 40.73 for female flowers, while heterobeltiosis exhibited decreases of 10.07% and 8.74%, respectively. Inbreeding affected 5.63% of male flowers and 1.59% of female flowers. The sex ratio demonstrated significant impacts: a decrease of 23.84% (Heterosis), an increase of 12.55% (heterobeltiosis), and an increase of 7.63% (Inbreeding).

In yield traits, the observed values of heterosis, heterobeltiosis, and inbreeding were notable, standing at 147.94%, 218.69%, and 81.16%, respectively. The number of fruits per vine showed effects of 23.89%, 85.84%, and 39.95%, respectively. For fruit weight, the values were 7.55%, 39.02%, and 59.56%. For fruit length, the impacts were -21.19%, 11.66%, and 17.02%. In fruit diameter, the observed effects were -21.19%, 2.59%, and 11.69%. For days to first fruit harvest, the effects were -33.42%, 0.39%, and 6.40%. For days to last fruit harvest, the values were -30.97%, 3.66%, and 18.50%. For cavity length, the values were 2.90%, 107.42%, and 43.38%. For cavity width, the values were -11.60%, 49.08%, and 40.97%. For flesh thickness, the effects were -27.21%, 7.11%, and 14.60%.In quality traits, for total soluble solids the heterosis, heterobeltiosis and inbreeding value of this trait were -22.62, 10.94% and 36.04%, respectively. For vitamin-c, the observed effects of heterosis, heterobeltiosis and inbreeding on this trait were 32.35, 66.67% and 61.78% respectively. In case of total sugars, heterosis, heterobeltiosis and inbreeding showed observed effects on this trait, recording -58.38,-44.47% and 18.37%, respectively. For titrable acidity, the values of heterosis, heterobeltiosis and inbreeding on this trait were -88.41, -81.67% and -127.27%, respectively. In β-carotene, heterosis, heterobeltiosis and inbreeding exhibited observed effects on this trait, showing -73.23, -71.44% and -48.87%, respectively.

In shelf life parameters, for shelf life (Days) at room temperature, the effects of heterosis, heterobeltiosis, and inbreeding were 9.35%, 14.63%, and 21.31%, respectively. For fruit firmness, the effects were 18.66%, 67.28%, and 23.08%. For rind thickness, the values were -35.29%, -36.54%, and 3.03%, respectively. For physiological loss in weight, the observed effects were -53.64%, 15.96%, and -76.56%, respectively.

The degree of inbreeding depression across crosses provides insights into the genetic compositions involved and elucidates whether significant impacts are observed. Heterosis and inbreeding depression were positive for specific traits including the number of fruits per vine, fruit weight, Yield per plant, cavity length, Vitamin-C, Shelf life (Days) at room temperature and fruit firmness. These findings indicate that these traits are subject to non-additive genetic effects in their inheritance (Sao and Metha 2010) [1] (Mauriya *et al.*, 2021) [10]. Additionally, positive heterosis in certain hybrids for these traits may result from the blending of two distinct genomic backgrounds, leading to genetic and epigenetic changes in gene expression.

The positive heterosis and negative inbreeding depression were not recorded in any trait to suggesting their primarily additive genetic control. Moreover, the negative inbreeding depression suggests a higher likelihood of obtaining favourable segregants in future generations. In contrast, traits such as the node number at which first perfect flower appears, days to the first appearance of male and perfect flowers, sex ratio, fruit length, fruit diameter, days to first fruit harvest, days to last fruit harvest, cavity width, flesh thickness, total soluble salts, total sugars and rind thickness demonstrate negative heterosis and positive inbreeding depression. This indicates that these traits rely more on non-additive genetic factors, including dominance and epistasis (Rohini *et al.*, 2016) [14] (Bhardwaj *et al.*, 2022) [4] (Samindre *et al.*, 2022) [15]. Such findings underscore the complex genetic interactions involved in shaping these traits and highlight the potential for genetic and phenotypic variability across hybrid populations.

Similarly, for traits such as node number at which first male flower appears, titrable acidity and β-carotene, both heterosis and inbreeding depression were negative, highlighting the influence of additive genetic mechanisms in their inheritance (Gupta *et al.*, 2018) [7] (Singh *et al.*, 2021, Khan *et al.*, 2017) [16, 9].

Table 1: Estimates of heterobeltiosis and inbreeding depression for growth, floral and yield attributes in F_2 segregating population of muskmelon

Traits	F_1 mean	Better parent	F_2 mean	Heterosis	Heterobeltiosis	Inbreeding depression
Plant growth parameters						
Node number at which first male flower appears	2.33	2.33	3.00	-43.98	0.14	-28.57
Node number at which first perfect flower appears	5.00	5.00	4.34	-36.14	0.00	13.20
Days to first appearance of male flower	32.67	36.33	30.83	-40.05	-10.07	5.63
Days to first appearance of perfect flower	38.33	42.00	37.72	-40.73	-8.74	1.59
Sex ratio (%)	11.93	10.60	11.02	-23.84	12.55	7.63
Yield parameters						
No of fruits per vine	4.33	2.33	2.60	23.89	85.84	39.95
Fruit length (cm)	12.16	10.89	10.09	-21.19	11.66	17.02
Fruit diameter (cm)	9.92	9.67	8.76	-27.93	2.59	11.69
Fruit weight (g)	1.14	0.82	0.46	7.55	39.02	59.56
Yield per plant (kg)	6.09	1.910	1.15	147.94	218.69	81.16
Days to first fruit harvest	86.67	86.33	81.12	-33.42	0.39	6.40
Days to last fruit harvest	104.00	100.33	84.76	-30.97	3.66	18.50
Cavity length (cm)	11.18	5.39	6.33	2.90	107.42	43.38
Cavity width (cm)	8.08	5.42	4.77	-11.60	49.08	40.97
Flesh thickness (cm)	2.26	2.11	1.93	-27.21	7.11	14.60
Quality parameters						
Total soluble solids (º Brix)	11.46	10.33	7.33	-22.62	10.94	36.04
Ascorbic acid (mg/100g)	27.00	16.20	10.32	32.35	66.67	61.78
Total sugars (%)	8.49	15.29	6.93	-58.38	-44.47	18.37
Titrable acidity (%)	0.11	0.60	0.25	-88.41	-81.67	-127.27
Beta carotene (µg/g)	3.97	13.90	5.91	-73.23	-71.44	-48.87
Shelf life parameters						
Shelf life (days) at room temperature	15.67	13.67	12.33	9.35	14.63	21.31
Fruit firmness (kg/cc)	4.55	2.72	3.50	18.66	67.28	23.08
Rind thickness (mm)	3.30	5.20	3.20	-35.29	-36.54	3.03
Physiological loss in weight (%)	4.65	4.01	8.21	-53.64	15.96	-76.56

Conclusion

This study elucidates the dynamics of inbreeding depression and heterosis in the F_2 population of muskmelon, providing valuable insights into genetic strategies for crop improvement. The traits such as the node of the first male flower emergence, titrable acidity and β-carotene suggesting their primarily additive genetic control. This implies that these traits are largely influenced by the cumulative effects of individual genes, making them more predictable and stable across generations. Harnessing this additive genetic control can aid in systematically improving these traits through selective breeding programmes, which emphasize the accumulation of desirable alleles. Overall, these parental cultivars and F_2 hybrids can be used and studied for further betterment in advanced generations for improvement of yield enhancement and addressing inbreeding depression for quality traits and shelf life in future breeding programmes.

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