CORRELATION AND PATH COEFFICIENT ANALYSIS IN MUSKMELON (*Cucumis melo* L.)

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Abstract

A set of 35 germplasm lines of muskmelon (*Cucumis melo* L.) were evaluated in a randomized block design with 3 replications during rabi (traditionally November–April) 2010-2011 at the Vegetable Research Station, Rajendranagar, Hyderabad, Andhra Pradesh, India to study the relationships among 18 quantitative traits pertaining to growth, earliness, and yield characters and to help breeders to determine the selection criteria for breeding programmes for fruit yield improvement. The lines RNMM-31, RNMM-32, RNMM-3, and RNMM-12 were promising with respect to fruit yield and quality. Fruit yield had a positive correlation with vine length, the number of primary branches per vine, fruit length, fruit diameter, average fruit weight, number of fruits per vine, fruit cavity length, fruit cavity width, rind thickness, and seed yield, while it had a negative correlation with the node numbers of the first pistillate flower, days to last fruit harvest, and pulp thickness. Direct selection through fruit diameter will be effective. For the number of primary branches per vine, fruit length, fruit cavity length, and fruit cavity width which have a positive correlation with fruit yield and whose direct effects on fruit yield were negative or negligible, the indirect casual factors are to be considered simultaneously for selection. For the node numbers of the first pistillate flower and number of fruits per vine with a high positive direct effect on fruit yield, whose association with fruit yield was negative, a restricted simultaneous selection model is to be followed to nullify the undesirable indirect effects to make use of the direct effect.

Keywords: Character association, character contribution, selection indices, yield components

Introduction

Muskmelon (*Cucumis melo* L.) popularly known in India as *'kharbuja'* is an economically important fruit vegetable species of the cucurbitaceae family. It is subdivided into 6 cultivar groups - Cantaloupensis, Inodorus, Flexuosus, Conomon, Chito-Dudaim, and

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Momordica (Munger and Robinson, 1991). It is a highly cross-pollinated crop with a chromosome number 2n = 2 x = 24. A native of Middle Eastern countries, muskmelons spread slowly to other continents of the World. At present, it is an important dessert fruit of the tropics and subtropics. In India, muskmelon production is concentrated in the tropical and sub-tropical regions. It is grown under both riverbed and irrigated conditions for local and interstate sales and it is a high value dessert fruit as it fetches premium prices in the market compared with other fruits. It is gaining a lot of importance due to its short duration and high production potential as well as its high nutritive, medicinal, and industrial value. In spite of its recognized potential and multiple virtues, it is not suitable for commercial cultivation because of the low yielding potential of the current open-pollinated varieties and sub-optimal fruit quality.

The major emphasis in muskmelon breeding is on the development of high yielding varieties coupled with good fruit quality. In muskmelon, fruit yield is a complex quantitative trait as it is governed by a large number of genes and considerably affected by the environment. Hence, selection of lines based only on yield is not effective. Improvement of complex characters such as yield may be accomplished through the component approach of breeding. Therefore, understanding the genetic mechanism of growth, earliness, and yield related attributes would be very important for yield improvement. The influence of each character on yield could be known through correlation and path studies. Significant relationships between growth, earliness, and yield related attributes facilitate selection of high yielding lines (Singh, 2001). Investigation of the interrelationships between yield and its components will improve the efficiency of a breeding programme with appropriate selection criteria. Correlation and path coefficient analyses have been widely used in plant breeding to determine the nature of the relationships between yield and its contributing components. The success of most crop improvement programmes largely depends on the understanding of the relationship among characters and the magnitude of this relationship helps breeders to determine the selection criteria for breeding programmes.

Correlation studies alone are not indicative of interrelationships among heritable traits and thus this may lead to negative results (Bhatt, 1973). Correlation analysis indicates only the nature and extent of the association between yield and its components, but does not show the direct and indirect effects of different yield attributes on yield *per se*. In muskmelon, fruit yield is dependent on several characters which are mutually associated; these will in turn impair the true association existing between a component and fruit yield. A change in any one component is likely to disturb the whole network of cause and effect. Thus, each component has 2 paths of action *viz.*, the direct influence on fruit yield, and the indirect effect through components which are not revealed from the correlation studies. Path coefficient analysis measures the direct and indirect effect and permits the separation of the correlation coefficients into components of direct and indirect effect (Dewey and Lu, 1959). Wright (1921) proposed a method called path analyses which partition the estimated correlation into the direct and indirect effect. Dewey and Lu (1959) first carried out path analyses in plants.

Previously, several researchers (Lippert and Hall, 1982; Dhaliwal *et al.*, 1996; Somkuwar *et al.*, 1997; Abdalla and Aboul-Naser, 2002; Yadav and Ram, 2002; Choudhary *et al.*, 2003,Taha *et al.*, 2003; Singh and Lal, 2005; Zalapa *et al.* 2006; Reddy *et al.*, 2007;Musmade *et al.*, 2008; Tomar *et al.*, 2008; Feyzian *et a*l., 2009; Mehta *et al.*, 2009; Rad *et al.*, 2010) have explored the association of yield components with yield in muskmelon. In muskmelon, yield is correlated with several traits including days to anthesis, number of fruits per plant, average fruit weight, number of primary branches per plant, number of nodes on the main stem, stem length, internode length, and fruit shape index (Abdalla and Aboul-Naser, 2002; Taha *et al*., 2003). The traits often highlighted in this regard were plant length and primary branch (Taha *et al*., 2003), primary branch, fruit number per plant, and fruit weight per plant (Zalapa *et al*., 2006), and length, width, and shape index (Lippert and Hall 1982). In most of these studies, the number of primary branches per vine, fruit length, fruit width, and fruit weight are identified as important factors (effective characters) in melon yield (Taha *et al*., 2003; Zalapa *et al*., 2006).

The aim of the present study was genetic evaluation of the intraspecies variation of muskmelon on the basis of growth, earliness, and yield related attributes, which in turn was used: i) to determine the genetic relationship between growth, earliness, and fruit yield through correlation analysis, and ii) partitioning of genetic association through path coefficient analysis to assess the relative importance of direct and indirect effects of the above traits on fruit yield per plant. In this study, the relationship among yield components and their direct and indirect influences on the fruit yield of muskmelon were investigated.

Materials and Methods

Thirty five germplasm lines of muskmelon (Table 1) were evaluated in a randomized block design with 3 replications at the Experimental Farm, Vegetable Research Station, Rajendranagar, Hyderabad, Andhra Pradesh, India. The experiment was conducted during late winter season (November 2010-February 2011). Seeds were initially sown in plug trays in the shadenet house nursery in the first week of November 2010. The main field was ploughed, harrowed, leveled and then divided into growing units (single-row plots) of 3.6 m length and 2.0 m width. Each line was grown in an individual growing unit. Rows were spaced 2 m apart, while plants were spaced 0.6 m apart. Each line was represented by 1 row with 6 plants. Twenty five days old container raised seedlings were transplanted into the main field in the first week of December, 2010. Normal recommended cultural practices and plant protection measures were followed. The observations were recorded on 5 randomly selected plants from each line in each replication for vine length (cm), number of primary branches per vine, fruit length (cm), fruit diameter (cm), average fruit weight (g), number of fruits per vine, fruit cavity length (cm), fruit cavity width (cm), rind thickness (mm), pulp thickness (cm), total soluble solids (°Brix), seed yield (g/fruit), and fruit yield (kg/plant); and the observations were recorded on a whole plot basis for days to appearance of first staminate flower, days to appearance of first pistillate flower, node numbers of the first pistillate flower, days to first fruit harvest, days to last fruit harvest, and total yield per plant. Growth attributes like vine length and the number of primary branches per vine were recorded at final harvest. Earliness attributes like days to appearance of first staminate flower, days to appearance of first pistillate flower, and node numbers of the first pistillate flower were recorded at the flowering stage, while days to first fruit harvest and days to last fruit harvest were recorded at the first and final harvest of the fruits picked at the half-slip stage, respectively. Fruit traits like fruit length, fruit diameter, average fruit weight, fruit cavity length, fruit cavity width, rind thickness, pulp thickness, and seed yield were recorded on 5 fruits picked at the half-slip stage at first harvest in each replication. Total soluble solids were recorded in °Brix with a hand refractometer on 5 fruits picked at the half-slip stage at first harvest. The number of fruits picked from all the pickings from the individual line in each replication was summed up and divided by the total number of plants per plot to arrive at the total number of fruits per plant. The quantity of fruits picked from all the pickings from the individual line in each replication were summed up and divided by the total number of plants per plot to arrive at the total yield per plant. The analysis was carried out by applying standard statistical techniques for analysis of variance to establish the

Table 1. Salient features of 35 genotypes of muskmelon

Genotype	Vine length (cm)	Number of primary branches per vine	Days to appearance of first staminate flower	Days to appearance of first pistillate flower	Node numbers of first pistillate flower	Days to first fruit harvest	Days to last fruit harvest	Fruit length (cm)	Fruit diameter (cm)
RNMM-1	79.27	3.33	49.27	58.87	4.87	84.73	104.07	10.80	9.20
RNMM-2	85.00	3.40	48.20	62.73	4.53	91.67	110.60	11.57	9.08
RNMM-3	75.60	4.20	40.93	55.93	4.47	82.27	98.07	16.00	9.15
RNMM-4	77.87	2.73	48.40	59.60	4.67	94.60	116.33	7.92	7.83
RNMM-5	87.60	2.67	45.87	57.60	4.60	84.60	104.40	12.00	9.27
RNMM-6	65.07	2.93	45.80	57.47	5.20	83.07	104.23	10.12	8.87
RNMM-7	93.67	3.20	39.20	50.07	3.53	81.67	100.20	11.63	8.33
RNMM-8	77.40	3.33	51.93	65.47	5.33	96.67	119.13	10.53	8.64
RNMM-9	85.80	3.27	48.07	54.20	3.73	94.67	114.13	12.55	8.37
RNMM-10	75.27	3.07	51.73	62.80	5.33	92.67	118.40	12.03	8.68
RNMM-11	79.67	3.67	49.47	60.47	4.73	84.53	105.20	9.77	8.37
RNMM-12	88.53	3.40	40.80	54.53	4.80	87.67	108.00	9.80	8.87
RNMM-13	82.33	3.13	42.13	58.27	3.47	96.00	119.67	11.07	8.25
RNMM-14	103.87	2.33	54.80	64.40	5.73	91.00	111.27	8.78	7.89
RNMM-15	63.47	2.60	38.80	50.47	4.00	87.67	107.93	8.65	7.91
RNMM-16	63.80	2.27	38.80	53.93	5.13	83.07	103.00	9.22	7.53
RNMM-17	80.33	2.93	39.20	54.47	4.33	82.67	102.33	11.45	8.24
RNMM-18	87.93	2.67	47.53	60.20	4.13	96.67	115.87	8.75	8.25
RNMM-19	68.07	2.47	49.47	58.27	4.47	83.07	103.67	8.47	8.17
RNMM-20	73.60	2.60	49.33	60.00	4.33	94.40	115.07	11.02	8.21
RNMM-21	76.07	2.60	51.87	58.93	4.40	85.87	106.00	8.30	8.59
RNMM-22	81.40	3.33	55.20	62.60	4.73	89.07	109.40	13.55	8.20
RNMM-23	68.33	2.53	38.80	56.33	5.07	82.53	99.67	11.25	8.51
RNMM-24	65.87	2.93	41.27	55.60	4.00	81.33	100.07	9.12	8.18
RNMM-25	86.00	3.07	46.93	61.93	6.40	86.47	105.93	10.62	9.22
RNMM-26	76.93	2.80	50.27	62.40	4.47	94.00	114.33	10.78	8.75
RNMM-27	69.40	2.47	43.53	53.27	4.20	81.67	100.33	11.72	9.03
RNMM-28	67.60	3.00	47.27	59.87	4.47	86.73	106.67	12.30	8.70
RNMM-29	85.87	3.13	44.47	54.27	3.67	82.93	101.53	9.07	8.61
RNMM-30	92.47	3.27	48.53	62.33	5.53	94.33	115.80	8.25	7.95
RNMM-31	94.87	3.47	35.07	55.00	4.60	78.67	97.00	8.95	10.89
RNMM-32	109.73	3.07	35.27	54.73	4.53	80.67	99.27	16.33	7.38
RNMM-33	97.67	3.33	48.60	59.53	4.27	86.00	105.93	11.28	8.01
RNMM-34	87.33	4.00	49.00	58.47	4.40	83.40	105.07	10.42	9.10
RNMM-35	89.73	2.93	49.53	57.93	4.93	84.40	103.67	10.35	9.23
S. Em. ±	7.00	0.20	1.32	1.74	0.29	4.08	5.00	0.48	0.38
CV (%)	14.92	11.25	4.99	5.19	10.82	8.11	8.08	7.77	7.67

Table 1. Salient features of 35 genotypes of muskmelon (Continued)

Genotype	Vine length (cm)	Number of primary branches per vine	Days to appearance of first staminate flower	Days to appearance of first pistillate flower	Node numbers of first pistillate flower	Days to first fruit harvest	Days to last fruit harvest	Fruit length (cm)	Fruit diameter (cm)
CD (P = 0.05)	19.75	0.56	3.73	4.91	0.81	11.52	14.11	1.35	1.07
RNMM-1	400.00	2.53	6.13	5.13	1.47	1.75	6.70	3.41	1.01
RNMM-2	470.00	2.93	6.87	5.33	2.60	1.67	6.67	4.01	1.39
RNMM-3	772.33	2.20	10.83	6.00	2.13	1.43	6.22	6.90	1.70
RNMM-4	230.00	2.47	4.75	4.01	1.33	1.50	6.67	5.53	0.57
RNMM-5	426.67	2.47	5.57	5.67	1.57	1.57	6.75	4.33	1.06
RNMM-6	461.00	2.13	5.80	4.87	1.87	1.66	6.00	4.35	0.98
RNMM-7	473.33	2.60	6.53	4.43	2.13	1.77	6.47	5.36	1.24
RNMM-8	465.00	2.47	5.53	3.82	1.60	1.57	6.58	4.39	1.15
RNMM-9	476.67	2.73	8.00	4.15	1.53	1.49	6.90	4.39	1.31
RNMM-10	470.00	2.80	6.65	4.49	1.67	1.54	6.50	3.78	1.31
RNMM-11	393.33	2.33	5.90	4.20	2.00	1.59	6.77	4.23	0.91
RNMM-12	523.33	2.73	5.93	5.17	2.67	1.99	9.10	3.79	1.41
RNMM-13	456.67	3.07	5.92	3.93	1.77	1.53	6.73	3.27	1.42
RNMM-14	355.00	2.60	4.67	3.97	1.43	1.62	6.38	3.22	0.92
RNMM-15	238.33	3.07	4.47	4.07	1.27	1.46	6.30	3.07	0.72
RNMM-16	231.67	2.80	4.80	3.93	1.40	1.53	6.33	3.33	0.65
RNMM-17	353.33	3.47	5.83	4.62	1.63	1.53	6.50	3.76	1.21
RNMM-18	340.00	3.07	5.07	4.38	1.37	1.41	6.23	5.06	1.05
RNMM-19	403.33	2.67	4.80	4.43	2.00	1.47	6.50	3.53	1.08
RNMM-20	468.33	2.60	6.07	4.32	1.23	1.45	7.57	3.12	1.23
RNMM-21	393.33	3.33	4.67	4.43	1.47	1.53	6.62	3.91	1.31
RNMM-22	490.00	3.20	8.13	4.87	1.33	1.55	6.10	3.54	1.57
RNMM-23	415.00	2.93	6.43	4.40	1.67	1.56	6.23	3.90	1.22
RNMM-24	316.67	2.53	5.28	4.80	1.87	1.77	6.50	3.52	0.80
RNMM-25	356.67	2.93	6.27	5.40	1.30	1.67	6.75	3.29	1.05
RNMM-26	396.67	2.40	5.90	4.60	1.33	1.63	6.41	3.90	0.96
RNMM-27	423.33	2.60	7.56	5.50	1.80	1.88	7.50	4.36	1.10
RNMM-28	400.00	2.73	7.00	4.32	2.23	1.54	8.95	4.90	1.10
RNMM-29	410.00	3.27	5.47	4.18	1.47	1.58	6.57	3.77	1.34
RNMM-30	311.67	3.13	5.25	3.97	1.33	1.49	6.13	4.74	0.98
RNMM-31	520.00	2.33	6.03	6.53	2.57	1.89	6.00	5.31	1.22
RNMM-32	436.67	3.40	13.10	3.70	1.43	0.97	6.10	5.00	1.49
RNMM-33	428.33	3.00	6.47	4.57	1.73	1.46	6.70	4.59	1.29
RNMM-34	423.33	3.33	6.00	5.46	2.03	1.50	6.80	3.53	1.40
RNMM-35	450.00	3.07	5.55	5.18	1.17	1.60	7.43	3.97	1.37
S. Em. ±	17.94	0.32	0.33	0.25	0.14	0.11	0.15	0.22	0.15
CV (%)	7.46	19.94	9.18	9.37	14.36	11.62	3.97	9.35	21.77
CD (P = 0.05)	50.63	0.91	0.94	0.71	0.40	0.30	0.43	0.63	0.41

significance level among lines as described by Singh and Chaudhary (1985) and Steel and Torrie (1980). The correlation analysis was performed according to the method suggested by Weber and Moorthy (1952). Path coefficient analysis was carried out following the methods of Singh and Chaudhary (1985) and Steel and Torrie (1980).

Results and Discussion

The gain from selection in any crop improvement programme is dependent not only on the variability for the yield and other economic characters but also on the association among them in the population.

Mean Performance of Lines

Muskmelon breeders all over the world have been utilizing the available genetic resources to modify varieties to meet the ever-changing requirements of society. To turn muskmelon into a perfect candidate for sustainable agriculture, the crop should be attractive to both producers and consumers in terms of fruit yield and quality, respectively. In breeding programmes of muskmelon, the characters that need to be given emphasis include medium tall to tall vines, moderate branching habit, low position of first male and female flowering node, early maturity, and long fruiting period for enhanced productivity; medium sized fruits with thin skin, thick pulp, high total soluble solids, small seed cavity, and few seeds for enhanced fruit quality, and appearance and tolerance to biotic stresses for stable and sustainable production. Muskmelon germplasm needs to be evaluated for these traits to identify accessions to feed the breeding programmes.

The attainment of maximum fruit yield is one of the important objectives in most muskmelon breeding programmes. The ranges of mean values revealed sufficient variation for all the traits under study (Table 1). In the material under study, the maximum range of variability was observed for average fruit weight (230.00 to 772.33 g), followed by vine length (63.47 to 109.73 cm), and days to last fruit harvest (97.00 to 119.67) indicating the presence of high variability for these characters and thus offering greater scope for selecting desirable lines. On the basis of mean performance, the lines RNMM-31, RNMM-32, RNMM-3, and RNMM-12 were found to be promising with respect to fruit yield. From these results, it is evident that there was sufficient variation in the material under study. These findings are in agreement with those of earlier researchers (Torkadi *et al*., 2007; Idahosa *et al*., 2010).

The economic returns from muskmelon not only depend on fruit yield, but also on its quality, which is a conglomerate of several horticultural traits. Of the 18 characters under study, fruit cavity length, fruit cavity width, rind thickness, pulp thickness, total soluble solids, and seed yield largely determine the fruit quality in muskmelon. On the basis of these fruit quality attributes, out of 4 high yielding lines RNMM-31, RNMM-32, RNMM-3, and RNMM-12 identified on the basis of mean performance, only 3 lines RNMM-31, RNMM-3, and RNMM-12 were found to have reasonably good fruit quality.

Correlation Analysis

The existing relationships between traits are, generally, determined by the phenotypic and genotypic correlations. The phenotypic correlation measures the degree of association of 2 variables and is determined by genetic and environmental factors. The genotypic correlation on the other hand, which represents the genetic portion of the phenotypic correlation, is the only one of inheritable nature and is, therefore, used to orient breeding programmes. The correlation coefficient may also help to identify characters that have little or no importance in the selection programme. The existence of correlation may be attributed to the presence of the linkage or pleiotropic effect of genes or the physiological and development relationship or the environmental effect or to a combination of all.

A character by character examination of simple correlation coefficients revealed that different characters were differentially associated with each other (Table 2). In general, the estimates of genotypic correlation coefficients were higher in magnitude than their corresponding phenotypic correlation coefficients. The more significant genotypic association between different pairs of characters than the phenotypic correlation means that there is a strong association between those characters genetically, but the phenotypic value is lessened by the significant interaction of the environment. This indicates that the lines under study are reasonably stable and are less influenced by the environment. These findings are in agreement with the findings of earlier researchers (Yadav and Ram, 2002; Taha *et al*., 2003; Singh and Lal, 2005; Reddy *et al*., 2007; Tomar *et al*., 2008; Feyzian *et al*., 2009; Rad *et al*., 2010).

From the perusal of the genotypic correlation coefficients, it is evident that there was wide variation in the direction and magnitude of the association of various characters with fruit yield in muskmelon. In the present study, days to appearance of first staminate flower, days to appearance of first pistillate flower, and days to first fruit harvest had a non-significant correlation with fruit yield. In general, a non-significant correlation indicates that selection for the different characteristics could be done simultaneously and independently.

In muskmelon, vine length and number of primary branches per vine largely determine the photosynthetic area and flower and fruit bearing surface and are, thus, regarded as growth attributes. Muskmelon bears solitary fruits in leaf axils on the main vine as well as on primary branches. Taller vines with a greater number of primary branches accommodate a greater number of leaves and flowers on the vine, which will ultimately lead to higher fruit numbers and higher fruit production. In the present study, vine length had a significantly positive association with the number of primary branches per vine, number of fruits per vine, fruit cavity length, and fruit yield.

In muskmelon, days to appearance of first pistillate flower, days to appearance of first staminate flower, node numbers of the first pistillate flower, days to first fruit harvest, and days to last fruit harvest are the indicators of earliness. Early flowering not only gives early harvests and better returns but also widens the fruiting period of the plant. The lower the node numbers of the first pistillate flower and the lower the number of days to last fruit harvest, the higher is the productivity. Taha *et al*. (2003) also reported a positive association of earliness with fruit yield in muskmelon.

Fruit length, fruit diameter, average fruit weight, and number of fruits per vine are considered to be the fruit traits in muskmelon. Fruit length had a significantly positive association with vine length, number of primary branches per vine, average fruit weight, fruit cavity length, seed yield, and fruit yield, while it had a significantly negative association with days to appearance of first staminate flower, days to first fruit harvest, days to last fruit harvest, and pulp thickness. The present findings are in consonance with the findings of Taha *et al*. (2003) for association of fruit length with fruit width and fruit weight but in contrast with the association of fruit length with pulp thickness. Fruit diameter had a significantly positive association with the number of primary branches per vine, average fruit weight, fruit cavity width, rind thickness, pulp thickness, seed yield, and fruit yield, while it had a significantly negative association with days to first fruit harvest, days to last fruit harvest, and number of fruits per vine. The present findings are in consonance with the findings of Taha *et al*. (2003) for association of fruit diameter with fruit length, average fruit weight, and pulp thickness. Average fruit weight had a significantly positive association with vine length, number of primary branches per vine, fruit length, fruit diameter, fruit cavity length, fruit cavity width, rind thickness, seed yield, and fruit yield, while it had a significantly negative association with days to first fruit harvest, days to last fruit harvest, and number of fruits per vine. A similar

Table 2. Association among 17 growth, earliness, and fruit yield attributes in 35 genotypes of muskmelon

Character		(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Vine length, cm (1)	P	1.00	0.29**	-0.01	0.04	0.12	-0.07	-0.01	0.14	0.00
	G	1.00	0.30**	0.04	0.23*	-0.01	0.27**	0.05	0.24*	0.09
Number of primary branches per vine (2)	P		1.00	0.03	0.09	-0.06	-0.07	-0.03	0.33**	0.27**
	G		1.00	-0.04	0.06	-0.10	-0.11	-0.19	0.44**	0.5^{2**}
Days to appearance of first staminate flower (3)	P			1.00	0.70**	0.21*	0.34**	0.36**	-0.16	-0.03
	G			1.00	0.87**	0.39**	0.88**	0.93**	-0.19*	-0.10
Days to appearance of first pistillate flower (4)	P				1.00	0.37**	0.36**	0.33**	-0.08	0.01
	G				1.00	0.75**	1.00**	1.12**	-0.09	0.01
Node numbers of first pistillate flower (5)	P					1.00	0.07	0.11	-0.08	0.09
	G					1.00	0.08	0.12	-0.14	0.12
Days to first fruit harvest (6)	P						1.00	0.4^{8**}	-0.06	-0.13
	G						1.00	2.26**	-0.32**	-0.56**
Days to last fruit harvest (7)	P							1.00	-0.14	-0.16
	G							1.00	-0.32**	-0.53**
Fruit length, cm (8)	P								1.00	0.04
	G								1.00	0.02
Fruit diameter, cm (9)	P									1.00
	G									1.00
Average fruit weight, g (10)	P									
	G									
Number of fruits per vine (11)	P									
	G									
Fruit cavity length, cm (12)	P									
	G									
Fruit cavity width, cm (13)	P									
	G									
Rind thickness, mm (14)	P									
	G									
Pulp thickness, cm (15)	P									
	G									
Total soluble solids, °Brix (16)	P									
	G									
Seed yield, g fruit^{-1}, (17)	P									
	G									

$^{*, **}$ *Significant at 5 and 1% levels, respectively; P: phenotypic; G: genotypic*

Table 2. Association among 17 growth, earliness, and fruit yield attributes in 35 genotypes of muskmelon (Continued)

Character		(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)
Vine length, cm (1)	P	0.13	0.28**	0.24**	-0.02	-0.03	-0.16	-0.10	0.17	0.33**
	G	0.24*	0.36**	0.37**	0.10	0.06	-0.19	-0.10	0.29**	0.43**
Number of primary branches per vine (2)	P	0.53**	0.05	0.36**	0.30**	0.36**	0.06	-0.03	0.35**	0.45**
	G	0.69**	-0.35**	0.47**	0.47**	0.56**	0.05	0.06	0.44**	0.66**
Days to appearance of first staminate flower (3)	P	-0.02	-0.07	-0.26**	-0.12	-0.26**	0.01	0.06	-0.20*	-0.03
	G	-0.05	0.01	-0.29**	-0.18	-0.35**	-0.06	0.08	-0.28**	0.00
Days to appearance of first pistillate flower (4)	P	0.00	-0.05	-0.14	-0.07	-0.13	-0.10	-0.04	-0.08	0.01
	G	-0.01	-0.16	-0.16	-0.16	-0.22*	-0.12	-0.05	-0.18	-0.02
Node numbers of first pistillate flower (5)	P	-0.09	-0.04	-0.08	0.03	-0.17	-0.05	-0.04	-0.14	-0.10
	G	-0.14	-0.48**	-0.12	0.12	-0.20*	0.19	-0.10	-0.15	-0.33**
Days to first fruit harvest (6)	P	-0.12	-0.11	-0.13	-0.22*	-0.19*	-0.08	0.04	-0.06	-0.15
	G	-0.20*	0.55**	-0.39**	-0.82**	-0.55**	-0.35**	0.12	-0.20*	-0.01
Days to last fruit harvest (7)	P	-0.11	-0.01	-0.18	-0.31**	-0.19	-0.12	0.06	-0.10	-0.05
	G	-0.31**	0.21	-0.46**	-0.77**	-0.52**	-0.23*	0.11	-0.35**	-0.27**
Fruit length, cm (8)	P	0.60**	0.00	0.90**	0.20*	0.10	-0.18	0.01	0.29**	0.47**
	G	0.66**	0.09	0.92**	0.17	0.12	-0.53**	0.04	0.39**	0.81**
Fruit diameter, cm (9)	P	0.38**	-0.22*	0.00	0.66**	0.41**	0.45**	0.12	0.16	0.13
	G	0.60**	-0.77**	-0.03	1.06**	0.53**	0.76**	0.16	0.22*	0.47**
Average fruit weight, g (10)	P	1.00	-0.15	0.55**	0.48**	0.43**	0.12	0.09	0.38**	0.68**
	G	1.00	-0.66**	0.61**	0.54**	0.51**	0.09	0.12	0.47**	0.96**
Number of fruits per vine (11)	P		1.00	0.03	-0.18	-0.14	-0.22**	-0.06	-0.18	0.61**
	G		1.00	0.17	-0.63**	-0.79**	-1.19**	-0.02	-0.78**	0.42**
Fruit cavity length, cm (12)	P			1.00	0.14	0.11	-0.25**	-0.04	0.41**	0.45**
	G			1.00	0.14	0.16	-0.59**	-0.04	0.50**	0.76**
Fruit cavity width, cm (13)	P				1.00	0.41**	0.41**	0.07	0.18	0.22*
	G				1.00	0.52**	0.63**	0.09	0.26**	0.41**
Rind thickness, mm (14)	P					1.00	0.37**	0.28**	0.24*	0.25*
	G					1.00	0.59**	0.34**	0.34**	0.36**
Pulp thickness, cm (15)	P						1.00	0.20*	-0.08	-0.07
	G						1.00	0.46**	-0.20*	-0.22*
Total soluble solids, °Brix (16)	P							1.00	-0.10	0.04
	G							1.00	-0.10	0.18
Seed yield, g fruit^{-1}, (17)	P								1.00	0.14
	G								1.00	0.26**

$^{*, **}$ *Significant at 5 and 1% levels, respectively; P: Phenotypic; G: Genotypic* association of average fruit weight with vine length, fruit length, fruit diameter, and fruit yield was also reported by Taha *et al*. (2003). The number of fruits per vine had a significantly positive association with vine length, days to first fruit harvest, days to last fruit harvest, and fruit yield, while it had a significantly negative association with the number of primary branches per vine, node numbers of the first pistillate flower, fruit diameter, average fruit weight, fruit cavity width, rind thickness, pulp thickness, and seed yield.

Pulp thickness had a significantly positive association with fruit diameter, fruit cavity width, rind thickness, and total soluble solids, while it had a significantly negative association with days to first fruit harvest, days to last fruit harvest, fruit length, number of fruits per vine, fruit cavity length, seed yield, and fruit yield. The present findings are in consonance with the findings of Taha *et al*. (2003) for association of pulp thickness with vine length, fruit length, fruit diameter, and average fruit weight. Total soluble solids had a significantly positive association with rind thickness and pulp thickness.

Fruit cavity length had a significantly positive association with vine length, the number of primary branches per vine, fruit length, average fruit weight, seed yield, and fruit yield, while it had a significantly negative association with days to appearance of first staminate flower, days to first fruit harvest, days to last fruit harvest, and pulp thickness. Fruit cavity width had a significantly positive association with the number of primary branches per vine, fruit diameter, average fruit weight, rind thickness, pulp thickness, seed yield, and fruit yield, while it had a significantly negative association with days to first fruit harvest, days to last fruit harvest, and number of fruits per vine. Rind thickness had a significantly positive association with the number of primary branches per vine, fruit diameter, average fruit weight, fruit cavity width, pulp thickness, total soluble solids, seed yield, and fruit yield, while it had a significantly negative association with days to appearance of first staminate flower, days to appearance of first pistillate flower, node numbers of the first pistillate flower, days to first fruit harvest, days to last fruit harvest, and number of fruits per vine. In the present investigation, fruit yield was positively correlated with vine length, the number of primary branches per vine, fruit length, fruit diameter, average fruit weight, number of fruits per vine, fruit cavity length, fruit cavity width, rind thickness, and seed yield.

Yield is an end product of the multiplication interaction between the yield components. Grafius (1959) suggested that there may not be genes for yield *per se*. Rather there could be genes which govern the inheritance of component characters and there is no separate gene system for yield *per se*. Griffing (1956) has suggested the possibility of working with yield components which are likely to be more simply inherited than by itself. The contribution of the components of yield is through the component compensation mechanism (Adams 1967). Since then component breeding, rather than direct selection on yield, has commonly been practiced. This method, in general, assumes strong associations of yield with a number of characters making up yield. In the present study, vine length, number of primary branches per vine, node number of first pistillate flower, days to last fruit harvest, fruit length, fruit diameter, average fruit weight, average fruit weight, number of fruits per vine, fruit cavity length, fruit cavity width, rind thickness, pulp thickness, and seed yield with a significant correlation with fruit yield are thus identified as component characters of muskmelon. Therefore, rapid improvement in fruit yield of muskmelon is expected to result if selection is practiced for these component characters. The rate of improvement is expected to be rapid if differential emphasis is laid on the component characters during selection. The basis of differential emphasis could be the degree of influence of the component characters on the economic characters of interest.

Path Coefficient Analysis

After getting information from the results of the correlation analysis, the path coefficient analysis was done to determine the direct and indirect effects of traits on fruit yield. The estimates of the correlation coefficients revealed only the relationship between yield and yield associated traits, but did not show the direct and indirect effects of different traits on fruit yield *per se*. This is because the attributes which are in association do not exist by themselves, but are linked to other components.

Partitioning of the phenotypic and genotypic correlation co-efficients of the 17 characters on yield into direct and indirect effects was done (Table 3). At the phenotypic level, 2 characters, average fruit weight and number of fruits per vine, had positively high direct effects on fruit yield in muskmelon. At the genotypic level, the character fruit length had a negligible direct effect on fruit yield in muskmelon. The characters vine length, days to appearance of first pistillate flower, node numbers of the first pistillate flower, fruit diameter, average fruit weight, number of fruits per vine, rind thickness, total soluble solids, and seed yield had positively high direct effects. These findings are in consonance with those of Singh and Lal, (2005), Reddy *et al*. (2007) for vine length, Dhaliwal *et al*. (1996) for number of days to first pistillate flower, Choudhary *et al*. (2003) for average fruit weight, Choudhary *et al*. (2003), Singh and Lal (2005), Reddy *et al*. (2007), Tomar *et al*. (2008), and Mehta *et al*. (2009) for number of fruits per vine, Singh and Lal, (2005) for rind thickness, and Singh and Lal (2005), Tomar *et al*. (2008), and Mehta *et al*. (2009) for total soluble solids. The characters number of primary branches per vine, days to appearance of first staminate flower, days to first fruit harvest, days to last fruit harvest, fruit cavity length, fruit cavity width, and pulp thickness had negatively high direct effects on fruit yield in muskmelon. These findings are in consonance with those of Somkuwar *et al*. (1997) for days to first fruit harvest.

The genotypic direct effect of fruit diameter on fruit yield per plant (0.47) was almost equal to its genotypic correlation coefficient with fruit yield (0.55). Thus correlation explains the true relationship between fruit diameter and fruit yield and direct selection through this trait will be effective. The characters number of primary branches per vine, fruit length, fruit cavity length, and fruit cavity width had a significantly positive correlation with fruit yield, but their direct effects on fruit yield were significantly negative or negligible. In such cases, the indirect casual factors are to be considered simultaneously for selection. Under the conditions, where the correlation coefficient may be negative but the direct effect is positive and high, a restricted simultaneous selection model is to be followed, i.e., restrictions are to be imposed to nullify the undesirable indirect effects in order to make use of the direct effect. The genotypic path coefficient analysis revealed that node numbers of the first pistillate flower had a high positive direct effect on fruit yield, though its association with fruit yield was significantly negative. Under these circumstances, a restricted simultaneous selection model is to be followed to nullify the undesirable indirect effects to make use of the direct effect. Character association revealed by path analysis could be influenced by different factors including: (i) the germplasm used, (ii) the environment, and (iii) the traits used in the analysis. Therefore, the general applicability of the path analysis can be ascertained by analysis of data from different sets of germplasm under different production conditions.

The residual factor determines how best the casual factors account for the variability of the dependent factor, the fruit yield in this case. The residual effects were 0.15 and 0.44, which were of low and high magnitude at the phenotypic and genotypic levels, respectively. The variables studied explain about 85% and 56% of the variability

Table 3. Direct and indirect effects of component characters on fruit yield in 35 genotypes of muskmelon

Character		(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Vine length, cm (1)	P	**0.04**	0.01	0.00	0.00	0.00	0.00	0.00	0.01	0.00
	G	**0.30**	0.09	0.01	0.07	0.00	0.08	0.01	0.07	0.03
Number of primary branches per vine (2)	P	-0.01	**-0.02**	0.00	0.00	0.00	0.00	0.00	-0.01	-0.01
	G	-0.12	**-0.41**	0.02	-0.02	0.04	0.05	0.08	-0.18	-0.21
Days to appearance of first staminate flower (3)	P	0.00	0.00	**0.02**	0.01	0.00	0.01	0.01	0.00	0.00
	G	-0.03	0.03	**-0.74**	-0.65	-0.29	-0.66	-0.69	0.14	0.08
Days to appearance of first pistillate flower (4)	P	0.00	0.00	0.03	**0.04**	0.02	0.01	0.01	0.00	0.00
	G	0.17	0.04	0.66	**0.75**	0.56	0.75	0.84	-0.07	0.01
Node numbers of first pistillate flower (5)	P	0.00	0.00	0.00	-0.01	**-0.02**	0.00	0.00	0.00	0.00
	G	-0.02	-0.15	0.60	1.15	**1.53**	0.12	0.18	-0.21	0.19
Days to first fruit harvest (6)	P	0.00	0.00	0.00	-0.01	0.00	**-0.01**	-0.01	0.00	0.00
	G	-0.17	0.07	-0.56	-0.63	-0.05	**-0.63**	-1.43	0.20	0.35
Days to last fruit harvest (7)	P	0.00	0.00	0.01	0.01	0.00	0.02	**0.03**	0.00	-0.01
	G	-0.07	0.24	-1.22	-1.47	-0.16	-2.97	**-1.31**	0.42	0.70
Fruit length, cm (8)	P	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**-0.01**	0.00
	G	0.02	0.04	-0.02	-0.01	-0.01	-0.03	-0.03	**0.08**	0.00
Fruit diameter, cm (9)	P	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**-0.01**
	G	0.05	0.29	-0.06	0.01	0.07	-0.31	-0.29	0.01	**0.55**
Average fruit weight, g (10)	P	0.10	0.41	-0.02	0.00	-0.07	-0.09	-0.09	0.47	0.30
	G	1.06	3.07	-0.23	-0.04	-0.63	-0.88	-1.39	2.96	2.70
Number of fruits per vine (11)	P	0.20	0.03	-0.05	-0.04	-0.03	-0.07	0.00	0.00	-0.16
	G	0.52	-0.50	0.02	-0.23	-0.68	0.78	0.30	0.13	-1.10
Fruit cavity length, cm (12)	P	0.01	0.01	-0.01	-0.01	0.00	0.00	-0.01	0.03	0.00
	G	-2.08	-2.61	1.64	0.92	0.66	2.16	2.57	-5.13	0.14
Fruit cavity width, cm (13)	P	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.01
	G	-0.10	-0.47	0.18	0.16	-0.12	0.82	0.77	-0.17	-1.06
Rind thickness, mm (14)	P	0.00	0.01	-0.01	0.00	-0.01	-0.01	-0.01	0.00	0.01
	G	0.08	0.71	-0.44	-0.28	-0.25	-0.69	-0.66	0.15	0.67
Pulp thickness, cm (15)	P	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01
	G	0.74	-0.19	0.25	0.47	-0.74	1.37	0.90	2.06	-2.95
Total soluble solids, °Brix (16)	P	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	G	-0.13	0.08	0.12	-0.07	-0.14	0.17	0.15	0.05	0.22
Seed yield, g fruit^{-1}, (17)	P	-0.01	-0.01	0.01	0.00	0.01	0.00	0.00	-0.01	-0.01
	G	0.22	0.33	-0.21	-0.14	-0.11	-0.15	-0.26	0.29	0.16

Phenotypic residual effect = 0.15; Genotypic residual effect = 0.44
P: Phenotypic; G: Genotypic; r: correlation coefficient
Diagonal (bold) values are direct effects; Values above and below diagonal are indirect effects

Table 3. Direct and indirect effects of component characters on fruit yield in 35 genotypes of muskmelon (Continued)

Character		(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	'r' with fruit yield plant^{-1}
Vine length, cm (1)	P	0.01	0.01	0.01	0.00	0.00	-0.01	0.00	0.01	0.33**
	G	0.07	0.11	0.11	0.03	0.02	-0.06	-0.03	0.09	0.43**
Number of primary branches per vine (2)	P	-0.01	0.00	-0.01	-0.01	-0.01	0.00	0.00	-0.01	0.45**
	G	-0.28	0.14	-0.19	-0.19	-0.23	-0.02	-0.02	-0.18	0.66**
Days to appearance of first staminate flower (3)	P	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.03
	G	0.04	-0.01	0.22	0.13	0.26	0.05	-0.06	0.20	0.00
Days to appearance of first pistillate flower (4)	P	0.00	0.00	-0.01	0.00	-0.01	0.00	0.00	0.00	0.01
	G	-0.01	-0.12	-0.12	-0.12	-0.17	-0.09	-0.04	-0.14	-0.02
Node numbers of first pistillate flower (5)	P	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.10
	G	-0.22	-0.73	-0.18	0.18	-0.31	0.29	-0.15	-0.23	-0.33**
Days to first fruit harvest (6)	P	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.15
	G	0.12	-0.35	0.25	0.52	0.35	0.22	-0.07	0.13	-0.01
Days to last fruit harvest (7)	P	0.00	0.00	-0.01	-0.01	-0.01	0.00	0.00	0.00	-0.05
	G	0.41	-0.27	0.60	1.01	0.69	0.30	-0.14	0.45	-0.27**
Fruit length, cm (8)	P	-0.01	0.00	-0.01	0.00	0.00	0.00	0.00	0.00	0.47**
	G	0.05	0.01	0.07	0.01	0.01	-0.04	0.00	0.03	0.81**
Fruit diameter, cm (9)	P	0.00	0.00	0.00	-0.01	-0.01	-0.01	0.00	0.00	0.13
	G	0.33	-0.42	-0.01	0.58	0.29	0.42	0.09	0.12	0.47**
Average fruit weight, g (10)	P	**0.79**	-0.12	0.43	0.37	0.34	0.09	0.07	0.30	0.68**
	G	**4.48**	-2.94	2.71	2.41	2.28	0.41	0.53	2.11	0.96**
Number of fruits per vine (11)	P	-0.11	**0.71**	0.02	-0.13	-0.10	-0.16	-0.04	-0.13	0.61**
	G	-0.94	**1.43**	0.24	-0.90	-1.12	-1.70	-0.02	-1.11	0.42**
Fruit cavity length, cm (12)	P	0.02	0.00	**0.04**	0.01	0.00	-0.01	0.00	0.02	0.45**
	G	-3.38	-0.92	**-5.59**	-0.77	-0.90	3.27	0.24	-2.77	0.76**
Fruit cavity width, cm (13)	P	0.00	0.00	0.00	**-0.01**	0.00	0.00	0.00	0.00	0.22*
	G	-0.54	0.63	-0.14	**-1.00**	-0.52	-0.63	-0.09	-0.26	0.41**
Rind thickness, mm (14)	P	0.01	0.00	0.00	0.01	**0.03**	0.01	0.01	0.01	0.25*
	G	0.64	-1.00	0.20	0.65	**1.27**	0.74	0.43	0.43	0.36**
Pulp thickness, cm (15)	P	0.00	0.00	0.00	0.01	0.01	**0.01**	0.00	0.00	-0.07
	G	-0.36	4.64	2.28	-2.45	-2.29	**-3.89**	-1.81	0.77	-0.22*
Total soluble solids, °Brix (16)	P	0.00	0.00	0.00	0.00	0.00	0.00	**0.00**	0.00	0.04
	G	0.17	-0.02	-0.06	0.12	0.48	0.65	**1.41**	-0.14	0.18
Seed yield, g fruit-1, (17)	P	-0.02	0.01	-0.02	-0.01	-0.01	0.00	0.00	**-0.04**	0.14
	G	0.36	-0.59	0.38	0.20	0.26	-0.15	-0.07	**0.76**	0.26**

Phenotypic residual effect = 0.15; Genotypic residual effect = 0.44
P: Phenotypic; G: Genotypic; r: correlation coefficient
Diagonal (bold) values are direct effects; Values above and below diagonal are indirect effects

at the phenotypic and genotypic levels, respectively, in the fruit yield. The high magnitude of the residual factor at the genotypic level seems to be due to low and non-significant correlations of days to appearance of first staminate flower, days to appearance of first pistillate flower, days to first fruit harvest, and total soluble solids. Besides, some other factors which have not been considered here need to be included in the analysis to account fully for the variation at the genotypic level in the fruit yield of muskmelon.

Conclusions

Vine length, number of primary branches per vine, node numbers of the first pistillate flower, days to last fruit harvest, fruit length, fruit diameter, average fruit weight, number of fruits per vine, fruit cavity length, fruit cavity width, rind thickness, pulp thickness, and seed yield are identified as yield components in muskmelon. Direct selection through fruit diameter will be effective due to its strong positive correlation and high direct effect. Indirect simultaneous selection is effective for the number of primary branches per vine, fruit length, fruit cavity length, and fruit cavity width. A restricted simultaneous selection model is to be followed for node numbers of the first pistillate flower and number of fruits per vine.

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