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Estimation of heritability and genetic variability in selected F_1 bitter gourd population for yield and its contributing traits

[1,*]Wan Rozita, W.E., [2]Noraziyah, A.A.S., [1]Suhana, O., [1]Farahzety, A.M., [1]Norfadzilah, A.F. and [1]Rosniza, K.

[1]Horticulture Research Centre, MARDI Headquarters, 43400, Serdang, Selangor, Malaysia
[2]Department of Biological Sciences and Biotechnology, Faculty of Science and Technology, Universiti Kebangsaan Malaysia, 43600, Bangi, Selangor, Malaysia

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Abstract

Bitter gourd is one of the potential vegetables that has been clinically proven with several uses due to its medicinal advantages. However, it is less popular than other vegetable crops. Hence, this study was conducted to obtain detailed information on important agronomic traits and determine the pattern of inheritance of morphological traits in bitter gourd. Four F_1 populations, P105 × P11, P11 × P92, P92 × P13 and P13 × P92 have been successfully generated from the hybridisation of four genotypes parental lines (P11, P13, P92 and P105). The result of analysis of variance showed that the parents and the F_1 populations were significantly different ($p < 0.01$) in terms of vine length at 90 days after sowing, days of the first harvest after flowering, fruit number, fruit weight, fruit length, fruit girth, flesh thickness and total yield per plant. It also exhibited significantly different ($p < 0.05$) on days of to first male and female flower appearances. F_1 progeny P11 × P92 recorded the highest total yield per plant (5376 g), followed by the parent P92 (4885 g). Positive and significant correlations were observed between total yield per plant and its contributing traits such as fruit weight (r = 0.81), fruit length (r = 0.73), flesh thickness (r = 0.65), fruit girth (r = 0.63), vine length at 90 days after sowing (r = 0.33) and fruit number (r = 0.27). This indicates a higher magnitude of variability for selection with a larger scope of a breeding program in future. The heritability (h^2) values ranged from 68.16% for the days of the first harvest after flowering to 99.81% for fruit weight. The highest value of genetic advance (GA) was recorded by the total yield per plant (3220.53%) while the lowest value was displayed by days of the first harvest after flowering (1.35%), respectively. High heritability and GA values indicated that some characteristics could be inherited by the next generation.

1. Introduction

Bitter gourd (*Momordica charantia* L.) is commonly known as bitter cucumber, bitter melon and balsam pears. It belongs to the family Cucurbitaceae and probably originated in China and India (Grubben, 1977). Bitter gourd is one of the potential vegetable crops in Malaysia to be highlighted. It is rich in nutrients including ascorbic acid, phosphorus and iron and has been clinically proven with several uses owing to its medicinal advantages yet receives less attention than other vegetable crops. The bitter taste of fruit contains an alkaloid known as momordicin, which differs from another group of cucurbits (Mohan, 2005). It contains different kinds of plant active chemicals such as triterpenes, proteins, steroids, alkaloids, saponins, flavonoids, anti-bacterial, anti-parasitic, anti-viral, anti-fertility, hypoglycemic and anticarcinogenic (Ahmad *et al*., 2016).

Currently, Malaysia can only produce one-third of the total vegetables for the domestic market. The challenge faced by the vegetable industry is that domestic production is still not able to meet consumers' demands and needs. The total annual production of bitter gourd in 2017 was 17,649 metric tonnes with a value of RM 47,729.33, which then showed a decreasing trend in 2018 with 16,428 metric tonnes. However, value production had increased to RM 50,809.00. The rate of bitter gourd production in the country is very low compared to other countries. Still, the demand for this crop is increasing following the public awareness of practising a healthy lifestyle and dietary intake.

*Corresponding author.
Email: *wrozita@mardi.gov.my*

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This scenario makes the Malaysian vegetable market depend almost 90% on imported sources from abroad such as Thailand and China. Through the National Agro-Food Policy 2011-2020 (Kementerian Pertanian dan Industri Asas Tani Malaysia, 2011), Malaysia is still recording a relatively high value of food imports. Among the challenges include the rising prices of agricultural inputs, unpredictable global climate change, increasing food demand due to population growth and changes in dietary diets in communities. Most of the vegetable seeds grown domestically are imported from another country. Dependence on seeds from other countries burdens farmers due to the high price of hybrid seeds, thus causing instability in vegetable prices (DOA, 2018).

As a result, the Malaysian Agriculture Research and Development Institute (MARDI) has started a bitter gourd breeding program under the 'Rancangan Malaysia Ke-11' Development Fund (RMK-11). A total of 12 bitter gourds accessions namely P10, P11, P13, P92, P93, P94, PK12, P96, P97, P98, P101 and local accession Peria Katak (PK) were successfully collected and utilised in a conventional hybridisation program to generate new hybrids (Suhana *et al.,* 2018). Four potential parental lines namely P11, P13, P92 and P105 as well as their F_1 populations (P105 × P11, P11 × P92, P13 × P92 and P92 × P13) were used in this study. The objective of this study was to evaluate the genetic heritability and correlation among the genotypes and determine potential parental lines for future hybridisation programs.

2. Materials and methods

2.1 Plant materials and the preparation of the plot

A total of four parental lines and four F_1 populations were used in this study. The morphological traits of the parental lines are shown in Table 1. The study was conducted at MARDI Headquarters Station in Serdang, Selangor. The eight genotypes were planted in a randomised complete block design (RCBD) with three replications. The seedlings were planted in 1.0 m spacing within a row and 1.2 m within rows. Watering was done twice a day using an automatic irrigation system.

Table 1. Morphological traits of the four parental lines

No	Genotype	Source	Description
1	 P11	Breeder Seed Collections, Horticulture Research Centre, MARDI, Serdang.	• The shape of the fruit is cylindrical and light green. The fruit is categorised as long. • Several warts on the skin. • Fruit size is 26-29 cm long with a fruit diameter of 6-10 cm. Its weight is 333 -340 g per fruit.
2	 P92	Breeder Seed Collections, Horticulture Research Centre, MARDI, Serdang.	• The shape of the fruit is oblong and light green. The fruit is categorised as very long and has several warts on the skin. • Fruit size is 30-35 cm long with a fruit diameter of 8-12 cm. It weighs 450-480 g per fruit.
3	 P13	Breeder Seed Collections, Horticulture Research Centre, MARDI, Serdang.	• The shape of the fruit is cylindrical and dark green. The fruit is categorised as long and has an abundance of warts on the skin. • Fruit size is 27-30 cm long with a fruit diameter of 7-10 cm. Its weight is 130-160 g.
4	 P11	Breeder Seed Collections, Horticulture Research Centre, MARDI, Serdang.	• The shape of the fruit is ovate and light green. The fruit is categorised as oval and has an abundance of warts on the skin. • Fruit size is 8-12 cm long and fruit diameter is 1-5 cm. Its weight is 53-60 g.

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2.2 Plant growth performance and morphological characteristic data

Data were recorded consisting of growth performance such as vine length at 90 days after sowing (VL90), days to the first male (DMF) and female (DFF) flower appearance and days to the first harvest after flowering (FF). For yield and its contributing traits, the data were collected based on fruit number per vine (FN), individual fruit weight (FW), fruit length (FL), fruit diameter (FD), flesh thickness (FT) and total yield per plant (YLD).

2.3 Statistical analysis

All collected data were analysed using Statistical Analysis System (SAS) software. The simple statistics for each trait such as analysis of variance (ANOVA) and mean were calculated from the analysis. The correlation coefficients were analysed to evaluate the relationship between plant growth performance and yield components with YLD. The variance components and values of heritability were estimated according to the procedure described by Robinson and Comstock (1955).

3. Results and discussion

3.1 Qualitative characteristics of parental lines and F_1 generations

Qualitative characteristics assessment on crops in the field is very important in breeding studies to ensure that the objectives of the study can be achieved. Data on qualitative characteristics of the parental lines and F_1 generations are presented in Table 2. Normally, bitter gourd is harvested and eaten at an immature stage. The evaluation results found only parent P13 that was dark green in colour, while the other three parents (P11, P92 and P105) were light green. For the F_1 generation population, progeny P13 × P92 and P92 × P13 were found to be medium green, whereas two other progenies, namely P105 × P11 and P11 × P92, were light green. The main pigments found in immature fruit are chlorophyll A and chlorophyll B, which contribute to the bitter gourd's colour from white to dark green (Behera *et al*., 2013). The results showed that two populations of the F_1 generation, namely P105 × P11 and P11 × P92 inherited the light green colour from their respective parents. However, it was found that the other two F_1 generations, namely P13 × P92 and P92 × P13 were medium green in colour, which is different from the P13 parent (dark green) and P92 parent (light green). Thus, the colour inheritance on the fruit is different for each fruit in the group of cucurbits. Hu *et al.* (2002) found that the bitter gourd F_1 generation had a lighter colour than the parent due to the influence of incomplete dominant traits. Paris (2000) reported that the colour of the pumpkin skin is due to a combination of two genes; one dominant and the other recessive. Dhillon *et al.* (2016) reported that Vietnam and Thailand prefer light green bitter gourd, while South Asian countries prefer dark green. Therefore, the development of bitter gourd should be carried out by emphasising the colour of choice for bitter gourd fruit according to the preferable of respective countries.

Table 2. Qualitative traits of parental lines and F_1 generations

Population	Intensity of green colour of fruit	Shape of fruit	Number of warts
Parent			
P11	light	cylindrical	few
P13	dark	cylindrical	many
P92	light	oblong	few
P105	light	ovate	many
F1 generation			
P105 × P11	light	cylindrical	many
P11 × P92	light	cylindrical	few
P13 × P92	medium	cylindrical	medium
P92 × P13	medium	cylindrical	medium

In terms of fruit shape, the bitter gourd population shows various fruit shapes namely cylindrical, oblong and ovate (Table 2). Two parents, P11 and P13, are cylindrical, while P92 is oblong and P105 is ovate. However, the results obtained displayed that all populations of the F_1 generation were cylindrical in shape. The demand for bitter gourd fruit form varies according to countries in Asia (Dhillon *et al*., 2016). Vietnamese prefer oblong shapes, while Thais prefer cylindrical fruits. Whereas South Asians prefer small to medium and oblong fruit sizes.

Bitter gourd is a vegetable plant with wart skin. The degree of wart skin depends on the type of variety. There are three categories of wart skin; few, medium and many (The International Union for the Protection of New Varieties of Plants (UPOV), (2007). Parent P11, P92 and progeny P11 × P92 were categorised as few warts skin types. The medium wart skin category was recorded by progeny P13 × P92 and P92 × P13. Meanwhile, parent P13, P105, and progeny P105 × P11 were categorised as many wart skin types. Wart skin on bitter gourd is dominant to non-wart skin, which is controlled by a single nucleus gene (Dalamu *et al*., 2012).

3.2 Quantitative traits for plant growth performance and yield contributing traits

The selection of superior parents with the desired characteristics plays a crucial role in plant breeding studies. Yield and yield-contributing traits are important parameters and are highly demanded in plant breeding programs. Mean squares of ten quantitative traits of eight genotypes consisting of four parental lines and four F_1

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generations were shown in Table 3. Genotype means values for plant growth performance and yield contributing traits were shown in Table 4. The P13 × P92 progeny had the longest vine length at 90 days after sowing, which is 411.49 cm, followed by P92 × P13 progeny with 406.34 cm, while the P105 × P11 progeny was the shortest among progenies. The length of the vine is a very important character in bitter gourd cultivation as it is a contributing component to total yield (Patil *et al*., 2012; Gupta *et al*., 2016; Thakur *et al*., 2018).

Minimum days to first male flower appearance was recorded by P11 × P92 progeny by 59 days, followed by P92 × P13 (60.71 days) and P13 × P92 progeny (61.29 days). Male flower blooming was delayed in P105 × P11 progeny by 65 days. The P92 × P93 progeny was observed with the earliest days to the first female flower appearance (63.29 days), followed by P11 × P92, P13 × P92 and P105 × P11 progeny. Earliness is the desired character in bitter gourd, which reflects the potential economic aspect and affects the farmers' income. The minimum duration for the first male and female flower initiation is important in vegetable breeding as the hybridisation program can be performed earlier.

The optimal harvesting time of bitter gourd is difficult to determine since it is usually marketed and eaten before maturity. Generally, few parameters can be used as a guide to determine harvesting time; between 13 to 20 days after flowering, the colour of the fruit changes from dark to light green or through the visible wrinkles on the skin (Bahera *et al.*, 2007). The earliest days to the first harvest after flowering was recorded by P92 × P13 progeny, which was 13.57 days, followed by P13 × P92 (13.71 days), P105 × P11 (14 days), and P11 × P92 (15.43 days) (Table 4). Fruit numbers per vine, individual fruit weight, fruit length, fruit diameter and flesh thickness are the important yield-contributing traits. The results showed that genotypes were significantly different for these characters.

The total yield per plant is highly dependent on the total fruit number and average fruit weight per plant. The most fruit number was recorded by P92 × P13 and P11 × P92 progenies, which were 19 and 18.71, respectively, whereas P105 × P11 progeny recorded the fewest. A similar finding was also reported by Huang *et al.* (2010) in a previous bitter gourd study. The highest fruit weight was exhibited by P11 × P92 progeny, which was 297.76 g, followed by P92 × P13 (226.04 g), P105 × P11 (179.33 g) and P13 × P93 (178.01 g). Rani *et al*. (2014) reported that the average fruit weight of F_1 hybrids of bitter gourd in India is ranged from 58.82 to 98.57 g. The differences in the findings are due to different geographical areas and genotypes.

Fruit length and fruit diameter are components that influence the total weight of fruits. Round shape fruits normally have larger diameters than cylindrical shape fruits. In this study, the fruit length and fruit diameter ranged from 10.41 cm to 33.66 cm and 3.31 cm to 10.71 cm, respectively. Results revealed that P11 × P92 progeny recorded the longest fruit size of 28.24 cm, while the shortest was exhibited by P105 × P11 progeny with 21.27 cm. For the fruit diameter trait, the widest fruit was recorded by P11 × P92 progeny (8.99 cm) while the smallest was recorded by P105 × P11 progeny (6.77 cm). Reshmika *et al*. (2019) reported that the fruit length for bitter gourd in Kerala, India is ranged from 11.15 cm to 33.60 cm with a bigger fruit diameter ranging from 11.94 cm to 20.51 cm.

Fruit thickness is an important trait in the evaluation and selection of fruit quality. The thicker the filling, the larger the edible portion of the fruit. In the context of the bitter gourd crop, the fruit is not only eaten as a vegetable but is also demanded because of the nutrients inherent in the fruit itself. P11 × P92 progeny exhibited the highest value for fruit thickness and P13 × P92 progeny recorded the lowest value. P11 × P92 progeny exhibited the highest yield with a total value of 5376 g per plant, whereas P105 × P11 progeny exhibited the lowest with 1540.1 g per plant. Even though the P11 × P92 progeny took the longest period to mature in the field, it has the highest yield value components such as fruit number, fruit weight, fruit length, fruit diameter and flesh thickness giving the highest value compared to other progeny.

3.3 Correlation analysis

The correlation evaluates the magnitude and direction (positive or negative) of a connection that occurs between two or more properties. Correlation among all the characters studied was calculated and presented in Table 5. Yield showed a significant and positive association with vine length at 90 days after sowing (r = 0.33), fruit number (r = 0.27), fruit weight (r = 0.81), fruit length (r = 0.73), fruit diameter (r = 0.63) and fruit thickness (r = 0.65) but negative correlation with days to first female flower appearance (r = -0.31). This indicates that yield will be increased with the increase of vine length at 90 days after sowing, fruit number, fruit weight, fruit length, fruit diameter and fruit thickness. This result is supported by Yadav *et al.* (2013) and Pathak and Pahwa (2014) in their bitter gourd study. Besides, this study also agrees with the finding by Li *et al.* (1997) in which days to first flowering were negatively correlated with yield per plant in selected bitter gourd inbred lines.

It was observed that vine length at 90 days after

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Table 3. Mean squares of 10 quantitative traits for plant growth performance, yield and its contributing traits

Source	Df	VL90	DMF	DFF	FF	FN	FW (g)	FL (cm)	FD (cm)	FT (mm)	YLD (g)
Genotype	7	6765.54**	70.48*	51.62*	3.80**	103.51**	113012.77**	331.21**	33.55**	11.64**	17276639.1**
Rep	6	93.48	20.7	17.85	1.54	1.83	179.18	2.38	0.24	0.95	39847.9
Error	42	634.8	27.68	20.50	0.80	3.08	251.29	2.66	0.27	1.07	169049
Total	5										
CV		6.40	8.44	6.85	6.45	12.49	6.66	6.47	6.47	14.59	13.54
Mean		393.52	62.32	66.11	13.93	14.05	238.135	25.23	8.03	7.09	3036.14

**significant at 0.01 level, *significant at 0.05 level

VL90: Vine length 90 (DAS), DMF: Days to first male flower appearance, DFF: Days to first female flower appearance, FF: Days to first harvest after flowering, FN: Fruit number, FW: Fruit weight, FL: Fruit length, FD: Fruit diameter, FT: Fruit thickness, YLD: Total yield per plant

Table 4. Genotype means values for plant growth performance and yield contributing traits

Genotype	VL90	DMF	DFF	FF	FN	FW (g)	FL (cm)	FD (cm)	FT (mm)	YLD (g)
P11	347.63^{d}	68.57^{a}	70.29^{a}	14.14^{b}	10.00^{de}	337.21^{b}	28.04^{b}	8.93^{a}	8.19^{a}	3373.5^{c}
P13	371.53^{cd}	60.14^{b}	67.14^{abc}	12.86^{c}	13.43^{c}	159.20^{f}	27.44^{bc}	8.73^{d}	6.37^{b}	1996.2^{e}
P92	452.69^{a}	60.43^{b}	62.57^{c}	13.57^{bc}	11.29^{d}	469.77^{a}	33.66^{a}	10.71^{a}	9.19^{a}	4885.0^{b}
P105	383.30^{bc}	63.43^{ab}	69.14^{ab}	14.14^{b}	17.00^{b}	57.76^{g}	10.41^{e}	3.31^{c}	5.37^{b}	974.0^{g}
P105 × P11	384.99^{bc}	65.00^{ab}	66.29^{abc}	14.00^{b}	9.14^{e}	179.33^{e}	21.27^{d}	6.77^{b}	6.51^{b}	1540.1^{f}
P11 × P92	390.23^{bc}	59.00^{b}	64.29^{bc}	15.43^{a}	18.71^{ab}	297.76^{c}	28.24^{b}	8.99^{a}	8.25^{a}	5376.0^{a}
P13 × P92	411.49^{b}	61.29^{b}	65.86^{abc}	13.71^{bc}	13.86^{c}	178.01^{e}	25.93^{c}	8.25^{c}	6.29^{b}	2483.1^{d}
P92 × P13	406.34^{b}	60.71^{b}	63.29^{c}	13.57^{bc}	19.00^{a}	226.04^{d}	26.86^{bc}	8.55^{bc}	6.59^{b}	3661.0^{c}

Values are presented as mean. Values with different superscript within the same column are significantly different $p \leq 0.05$, based on DNMRT.

VL90: Vine length 90 (DAS), DMF: Days to first male flower appearance, DFF: Days to first female flower appearance, FF: Days to first harvest after flowering, FN: Fruit number, FW: Fruit weight, FL: Fruit length, FD: Fruit diameter, FT: Fruit thickness, YLD: Total yield per plant

Table 5. Phenotypic correlations among plant growth performance and yield contributing traits

Character	VL90	DMF	DFF	FF	FN	FW	FL	FD	FT
DMF	-0.14								
DFF	-0.48	0.23							
FF	-0.10	0.04	0.23						
FN	0.11	-0.20	-0.16	0.29*					
FW	0.36*	-0.04	-0.24	0.08	-0.27				
FL	0.27*	-0.15	-0.30*	-0.09	-0.18	0.81**			
FD	0.17	-0.03	-0.16	0.23	-0.24	0.76**	0.42*		
FT	0.22	-0.10	-0.27	0.14	-0.18	0.75**	0.58**	0.72**	
YLD	0.33*	-0.10	-0.31*	0.26	0.27*	0.81**	0.73**	0.63**	0.65**

**significant correlation at 0.01 level, *significant correlation at 0.05 level

VL90: Vine length 90 (DAS), DMF: Days to first male flower appearance, DFF: Days to first female flower appearance, FF: Days to first harvest after flowering, FN: Fruit number, FW: Fruit weight, FL: Fruit length, FD: Fruit diameter, FT: Fruit thickness, YLD: Total yield per plant

sowing had a highly significant and positive correlation with individual fruit weight (r = 0.36), fruit length (r = 0.27) and total yield per plant (r = 0.33). Days to the first harvest after flowering was recorded to have a positive correlation with fruit number (r = 0.29). This suggests that the size of the fruits will increase accordingly to the length of the vine. The result of this study showed that yield-attributed characteristics such as fruit number, fruit weight, fruit length, fruit diameter and fruit thickness have a significant and positive correlation with each other. This study indicates that the value of the yield-attributed characteristics has a significant impact on the overall total yield per plant. This result is supported by Triveni *et al*. (2021) in their bitter gourd study in Andhra Pradesh, India.

3.4 Heritability estimation

Heritability estimates and variance components of plant growth performance and yield contributing traits are shown in Table 6. This study revealed some important characteristics of the fruits known as total yield per plant, fruit weight, fruit length and fruit number that have recorded high phenotypic coefficient of variation (PCV) and genotypic coefficient of variation (GCV) values. The results showed that those characteristics are highly influenced by environmental factors. This indicates a higher magnitude of variability for those traits that allow the selection with a larger scope to be made for breeding purposes in the future. Previous researchers have also reported similar findings on bitter gourd crops (Gupta *et al*., 2016; Rahman *et al*., 2019).

Heritability data is essential as it can help breeders make better decisions about genotype selection and evaluation. Heritability values are classified into four different groups; more than 80% were categorised as high, 60-70% were moderate, 40-59% were intermediate and values below 40% were in a low category (Belay, 2018). This study showed that yield and its contributing traits such as individual fruit weight (99.81%), fruit length (99.30%), fruit diameter (99.30%), total yield per plant (99.15%), fruit number (97.42%), fruit thickness

Table 6. Estimation of genotypic and phenotypic coefficients of variation, heritability and genetic advance for growth performance and yield contributing traits parameters in bitter gourd genotypes

Character	Mean	$\sigma^2 g$	$\sigma^2 p$	GCV (%)	PCV (%)	h^2	*GA*
VL90	393.50	875.81	1034.51	7.52	8.17	92.01	60.96
DMF	62.32	6.11	13.03	3.97	5.8	68.49	5.09
DFF	66.11	4.45	9.57	3.19	4.68	68.16	4.34
FF	13.93	0.43	0.63	4.7	5.69	82.57	1.35
FN	14.05	14.35	15.12	26.96	27.67	97.42	7.8
FW	238.14	16108.78	16171.61	53.3	53.4	99.81	261.47
FL	25.23	46.94	47.6	27.15	27.35	99.30	14.11
FD	8.03	4.75	4.82	27.15	27.35	99.30	14.11
FT	7.09	1.51	1.78	17.33	18.8	92.17	2.53
YLD	3036.1	2443941.44	2486203.7	51.49	51.93	99.15	3220.53

VL90: Vine length 90 (DAS), DMF: Days to first male flower appearance, DFF: Days to first female flower appearance, FF: Days to first harvest after flowering, FN: Fruit number, FW: Fruit weight, FL: Fruit length, FD: Fruit diameter, FT: Fruit thickness, YLD: Total yield

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(92.17%), vine length at 90 days after sowing (92.01%) and days to the first harvest after flowering (82.57%) are easily inherited to the next generation as they exhibited high heritability and are less influenced by environmental factors. Similar findings have been reported by Waikhom and Kandasamy (2020) in bitter gourd in India, and Hanchinamani *et al*. (2011) in cucumber for several nodes per vines, days to first fruit harvest, fruit weight and total yield, Rabbani *et al*. (2012) for seed length in ridge gourd. Two traits that were recorded with moderate heritability were days to the first male and female flower appearance with values of 68.49% and 68.16%, respectively. High heritability does not guarantee desired selection results unless there is adequate additive gene action present from genetic advance (Srivastava and Jain, 1994). The high value of heritability along with the high value of genetic advance is the best condition for a selection program (Gandhi *et al.,* 1964).

4. Conclusion

From the findings, it can be concluded that agronomic characteristics such as fruit number, fruit weight, fruit length, fruit diameter and fruit thickness are the largest contributors to higher total yield in plants. The genotypes used in this study indicated a high amount of genetic variability values for most of the characteristics studied. This indicates that future bitter gourd breeding research will provide a broader range of evaluation and selection criteria. The genotype of the P11 × P92 progeny has been proven superior as it gave the highest total yield per plant (YLD) and was positively correlated with other YLD components such as fruit weight, fruit length, fruit diameter and fruit thickness. Hence, it might be used as a parent in future breeding studies.

Conflict of interest

The authors declare no conflicts of interest

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References

Ahmad, N., Hasan, N., Ahmad, Z., Zishan, M. and Zohrameena, S. (2016). *Momordica charantia*: For traditional uses and pharmacological actions. *Journal of Drug Delivery and Therapeutics,* 6(2), 40 –44. https://doi.org/10.22270/jddt.v6i2.1202

Bahera, T.K., Staub, J.E., Sanidha, B., and Philip, W.S. (2007). Bitter gourd and human health. *Medicinal and Aromatic Plant Science and Biotechnology*, 1 (2), 224-226.

Behera, T.K., Tiwari, H., Saha, S. and Singhal, P. (2013). Variatgourd genotypes at edible maturity stage. *Indian Journal of Horticulture,* 70(4), 599–602.

Belay, N. (2018). Genetic variability, heritability, correlation and path coefficient analysis for grain yield and yield component in maize (*Zea mays* L.) hybrids*., Advances in Crop Science and Technology*, 6(5), 1–9. https://doi.org/10.4172/2329-8863.1000399

Dalamu, Behera, T.K., Satyavati, C.T. and Pal, A. (2012). Generation mean analysis of yield related traits and inheritance of fruit colour and surface in bitter gourd. *Indian Journal of Horticulture Horticulture* 69(1), 65–69.

Dhillon, N., Phethin, S., Sanguansil, S. and Mc Creight, J.D. (2016). Early staminate flowering monoecious lines have potential as pollenizers for gynoecious hybrid bitter gourd cultivars. *Pakistan Journal of Agricultural Sciences,* 54(1), 27–33. https:// doi.org/10.21162/PAKJAS/17.4354

DOA (Department of Agriculture). (2018). Booklet Statistik Tanaman (Sub-Sektor Tanaman Makanan) 2018. Malaysia: Jabatan Pertanian, Malaysia. [In Bahasa Malaysia].

Gandhi, S.M., Sanghi, K.S., Natawat, K.S. and Bhatnagar, M.P. (1964). Genotypic variability and correlation coefficient relation to grain yield and a few other quantitative characters in Indian wheat. *Indian Journal of Genetics and Plant Breeding*, 24, 1 -8.

Grubben, G.J.H. (1977). Tropical Vegetable and their Genetic Resources. Rome, Italy: International Board for Plant Genetic Resources.

Gupta, N., Bhardwaj, M.L., Singh, S.P. and Sood, S. (2016). Genetic Diversity for Growth and Yield Traits in Bitter Gourd. *International Journal of Vegetable Science,* 22(5), 480–489. https:// doi.org/10.1080/19315260.2015.1083510

Hanchinamani, C.N., Patil, M.G., Dharmatti, P.R. and Mokashi, A.N. (2011). Studies on heritability and genetic advance in cucumber (*Cucumis sativus* L.). *Field Crops Research,* 41(1 to 3), 160-163.

Hu, K.L., Fu, Q.M., Wang, G.P. and Hu, Z.H. (2002). Studies on the genetics of fruit colour in bitter gourd (*Momordica* charantia L.). *China Vegetables,* 6, 11–12.

Huang, R., Fang, F., Zhuang, F., Kang, H., Huang, Y.

and Lou, H. (2010). Sowing date, plant density, fruits per plant and harvest time influenced yield and quality of hybrid seed of bitter gourd (*Momordica charantia*). *Acta Horticulturae,* 871, 395–402. https://doi.org/10.17660/ActaHortic.2010.871.54

Kementerian Pertanian dan Industri Asas Tani Malaysia. (2011). Dasar Agromakanan Negara (2011 – 2020). Putrajaya, Malaysia: Kementerian Pertanian dan Industri Asas Tani Malaysia

Li, J.W., Sun, S.R. and Rer, Y.H. (1997). Study on genetic correlation and path analysis of the main agronomic characters of cucumber. *Acta Agriculturae Universitatis Henanensis,* 31(3), 244-247

Mohan, L. (2005). Heterosis and combining ability in studies in bitter gourd (*Momordica charantia* L.). Dharwad, India: University of Agricultural Sciences, PhD Dissertation.

Paris, H.S. (2000). Quiescent intense (qi): A gene that affects young but not mature fruit colour intensity in *Cucurbita pepo*. *Journal of Heredity,* 91(4), 333–339. https://doi.org/10.1093/jhered/91.4.333

Pathak, M. and Pahwa, K. (2014). Genetic variability, correlation and path coefficient analysis in bitter gourd (*Momordica charantia* L.) *International Journal of Advanced Research,* 2(8),179-184.

Patil, S.A., Salimath, P.M., Dharmatti, P.R., Byadgi, A.S. and Yenagi, N. (2012). Heterosis and combining ability analysis for productivity traits in bitter gourd (*Momordica charantia* L.) commercial cucurbit belonging to the family Cucurbitaceae. *Karnataka Journal Agriculture and Science,* 25(1), 9–13.

Rabbani, M.G., Naher, M.J. and Hoque, S. (2012). Variability, character association and diversity analysis of ridge gourd (*Luffa acutangula* Roxb.) genotypes of Bangladesh. *SAARC Journal of Agriculture*, 10(2), 1-10. https://doi.org/10.3329/sja.v10i2.18319

Rahman, M., Tanzina, T., Bhuiyan, A., Kamrunnahar, Rahman M. and Zeba, N. (2019). Estimation of genetic variation and heritability in promising bitter gourd (*Momordica charantia* L.). *Journal of Experimental Biosciences,* 10(1), 13–22.

Rani, K.R., Reddy, K.R. and Raju, C.S. (2014). Association of fruit yield and component traits in segregating population of bitter gourd. *Plant Archives,* 14(1), 215–220.

Reshmika, P.K., Pradeepkumar, T., Krishnan, S. and Sureshkumar, P. (2019). Evaluation of bitter gourd hybrids. *Electronic Journal of Plant Breeding,* 10(4), 1617–1623. https://doi.org/10.5958/0975-928X.2019.00208.4

Robinson, H.F. and Comstock, R.E. (1955). Estimation of genetic and environmental variability in soybeans. *Agronomy Journal,* 23(2), 177–179.

Srivastava, A.N. and Jain, J.K. (1994). Variability and coheritability estimates for soybean. *Indian Journal of Genetics and Plant Breeding*, 54, 179-183.

Suhana, O., Mohd Zamri, K. and Mohd Isa, D. (2018). Evaluation of Selected Bitter Gourd Accessions for Yield and Related Traits, presented at 27th Malaysian Society of Plant Physiology Conference (MSPPC 2017). Johor, Malaysia: Pulai Springs Resort.

Thakur, V., Kumar, S., Tiwari, R. and Chormuler, S.R. (2018). Yield and yield contributing traits of bitter gourd (*Momordica charantia* L.) genotypes. *Journal of Pharmacognosy and Phytochemistry,* 7(3), 844–846.

The International Union for the Protection of New Varieties of Plants (UPOV). (2007). Bitter gourd. Guidelines for the conduct of tests for distinctness, uniformity and stability. Retrieved on August 2019 from UPOV Website: https://www.upov.int/edocs/tgdocs/en/tg235.pdf

Triveni, D., Uma Jyothi, K. and Dorajee Rao, A.V.D. (2021). Correlation and path analysis for yield and yield contributing traits in bitter gourd (*Momordica charantia* L.). *Vegetos,* 34, 944–950. https://doi.org/10.1007/s42535-021-00269-z

Waikhom, J.S. and Kandasamy, R. (2020). Studies on Genetic Variability in Bitter Gourd *(Momordica charantia* L.) Under Coastal Ecosystems. *Plant Archives*, 20(1), 2221-2224.

Yadav, M., Pandey, T.K., Singh, D.B. and Singh, G.K. (2013). Genetic variability, correlation coefficient and path analysis in bitter gourd. *Indian Journal of Horticulture*, 70(1), 144–149.

