GENETIC VARIABILITY AND CHARACTER ASSOCIATION OF YIELD AND YIELD CONTRIBUTING CHARACTERS IN BOTTLE GOURD (*Lagenaria siceraria* L.)

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BY

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CERTIFICATE

*This is to certify that thesis entitled,**" GENETIC VARIABILITY AND CHARACTER ASSOCIATION OF YIELD AND YIELD CONTRIBUTING CHARACTERS IN BOTTLE GOURD** (**Lagenaria siceraria L.)"** submitted to the faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE in GENETICS AND PLANT BREEDING**, embodies the result of a piece of bona fide research work carried out by **UTHKALIKA ROY BIPRA**, Registration No.: **19-10167** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.*

I further certify that such help or source of information, as has been availed of during the course of this investigation has been duly been acknowledged.

Dated: December, 2021

Prof. Dr Md. Sarowar Hossain

Supervisor

DEDICATED

TO

MY BELOVED FAMILY

SOME COMMONLY USED ABBREVIATIONS

FULL WORD	ABBREVIATIONS
Analysis of Variance	ANOVA
Agro-Ecological Zone	AEZ
Archives	*Arch.*
Bangladesh Bureau of Statistics	BBS
Biology	*Bio*.
Biological science	*Biosci.*
Bangladesh Agricultural Research Institute	BARI
Centimeter	Cm
Co-efficient of Variations	CV
Days after transplanting	DAT
Degrees of freedom	Df
Fruit Yield	FY
Fruit length	FL
Gram	Gm
Genotypic Variance	$\sigma^2{}_g$
Genetic Advance	GA
Genotypic Coefficient of Variation	GCV
Hectare	ha
Heritability in Broad Sense	h^2b
International	*Intl.*
Journal	*J.*
Kilogram	Kg
Least significant differences	lsd
Phenotypic Co-efficient of Variation	PCV
Meter	M
Murate of Potash	MP
Number	no.
Plant Height	PH
Percent	%
Phenotypic Variance	$\sigma^2{}_p$
Randomized Complete Block Design	RCBD
Relative Humidity	RH
Research	Res.
Square meter	m^2
Sher-e-Bangla Agricultural University	SAU
And Others	*et al*.

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GENETIC VARIABILITY AND CHARACTER ASSOCIATION OF YIELD AND YIELD CONTRIBUTING CHARACTERS IN BOTTLE GOURD (*Lagenaria siceraria* L.)

ABSTRACT

By

Uthkalika Roy Bipra

The experiment was carried out using ten genotypes of bottle gourd at the farm of Sher-e- Bangla Agricultural University, Dhaka to determine the genetic variability and to select the best performing genotypes for yield and its contributing traits during October 2020 to March 2021. The experiment was carried out in randomized complete block design with three replications. Analysis of variance revealed significant variations was exist among all the genotypes for the selected traits. The estimated variance components indicated environmental factors also contributed for the expression of the traits as the phenotypic co-efficient variation was higher than the genotypic counterparts. However, high heritability coupled with high genetic advance as percentage of mean was found in number of fruits per plant, fruit length, fruit diameter, fruit pedicel length, individual fruit weight, number of seeds per fruit, 100 seed weight, seed length, seed breadth and fruit yield per plant, hence inheritance of these traits was controlled by the additive gene actions whereas rest of the traits was governed by non-additive gene actions. Correlation study revealed that fruit yield per plant had a significant positive correlation with leaf breadth (cm), fruit diameter (cm), 100 seed weight (g) and individual fruit weight (kg) at the both genotypic and phenotypic levels. Moreover, path analysis revealed that days to 1st female flowering, leaf length, no. of male flowers, fruit length (cm), fruit diameter (cm), no. of fruits per plant, 100 seed weight (g) and individual fruit weight (g) showed positive direct effect on fruit yield per plant (kg) indicating that direct selection based on these traits may be helpful in evolving high yielding varieties of bottle gourd. Among the ten genotypes, G4 followed by G5, G7 and G10 showed the highest individual fruit weight while the highest fruit diameter was found in genotype G4 followed by G5, G7 and G8. Based on the individual fruit weight and fruit diameter that have a direct influence on generating the highest yield production; genotypes G4, G5, G7, G8 and G10 can be selected for developing the superior bottle gourd variety in future breeding programme.

CHAPTER I
INTRODUCTION

Cucurbitaceous vegetables are the largest family consisting of a maximum number of edible species in vegetable kingdom. Bottle gourd is one of the most famous members of this family. It is botanically known as *Lagenaria siceraria* L., having chromosome number, 2n = 22, (Bose and Som, 1986). The names "*lagenaria*" and "*siceraria*" are came from Latin words "lagena" for bottle and "sicera" for drinking utensil (Deepti, 2013). It is locally known as 'Lau' or 'Kodu' in Bangladesh. The bottle gourd is also called as water gourd, birdhouse gourd, trumpet gourd, calabash gourd, white flowered gourd etc. It is one such important vegetable of this family for fruit shape and other fruit characteristics, resulting in a variety of uses (Bisognin, 2002).

Bottle gourd is a vigorous annual climbing or prostrate plant from Cucurbitaceae family. It is diploid having solitary flowers and strictly cross pollinated due to its monoecious nature, bear more male flowers and less female flowers separately on the same plant (Sahu, 2016). The amount of cross pollination ranges from 60 to 80% (Chowdhury, 1979). Bees are the major pollinators. Most of the cucurbitaceous fruit crops grown worldwide in the tropical climates of India, Bangladesh, Sri Lanka, Indonesia, Malaysia, China, and Turkey as well as in most parts of Africa, Europe and South America. The bottle gourd most probably originated in Africa and from there was widely distributed in pre-Columbian times, perhaps by floating on the seas. It traveled to India, where it has evolved into numerous local varieties, and from India to China, Indonesia, and as far as New Zealand.

It can be grown in both rainy and summer seasons, and its fruits are available in the market, throughout the year. It is widely cultivated in tropics and subtropics, mostly grown for its fruit, which varies from in size and shape viz; globular, cylindrical, bottle-shaped or club-shaped. The fruits are fleshy and multi seeded. Fruits are either sweet in taste. It is cultivated worldwide for diverse uses such as for food, medicine, containers. Fresh bottle gourd fruit juice is used as medicine to cure various diseases (Ghule *et al.* 2007). Its seeds are the potential source of protein, lipid, macro and micro nutrients. Edible portion of bottle gourd is 86%. Among all cucurbits vegetables bottle gourd contains the maximum amount of minerals due to high keeping quality (Rashid, 1993). It contains many healing and medicinal properties. It contains iron, Vitamin C and B complex. Regular consumption of this vegetable provides relief to people suffering with digestive problems, diabetics and convalescents. Numerous health benefits are reported in bottle gourd including it is used to cure pain, ulcers and fever and is used for pectoral cough, asthma and other bronchial disorders using prepared syrup from the tender fruits (Upaganlawar and Balaraman, 2010). It is good for people suffering from biliousness and indigestion (Thamburaj and Singh, 2003).

The fruit make delicious supplement to the human diet and 100 g of fruits contain nearly 96g water, 0.2g protein, 0.1g fat, 2.5g carbohydrate, 0.6g fiber, 0.5g minerals, 20mg calcium, 10mg phosphorus, 0.7mg iron, 0.3mg thiamine, 0.01mg riboflavin and 0.2 mg niacin and energy 1.2 cal (Gopalan *et al.,* 1982). Their seeds are good sources of lipids and proteins and it contains 45 percent oil and 35 percent protein (Achu *et al.,* 2005).

It is an economically important crop cultivated worldwide for vegetable purpose. The fruits are used for variety of purposes, tender fruits used as vegetable and for preparing sweet dishes, rayta and pickle. In Bangladesh, it occupies about 18,892 ha with a total production of 226084 M. tons (BBS, 2018). The average yield is only 11.96 M. tons per hectare which is very low as compared to that in other tropical countries. On the other hand, high population growth rate is also putting increased pressure on the area of vegetable production. Bottle gourd can be grown with less cost and additional land is not required, can be grown in homestead area.

Crop improvement depends upon the magnitude of genetic variability and extent to which the desirable characters are heritable. The total variability can be partitioned into heritable and non-heritable components with the help of genetic parameters like phenotypic and genotypic co-efficient of variation, heritability and genetic advance. Heritable variation can be effectively studied in conjunction with genetic advance. High heritability alone is not enough to make efficient selection in segregating generation, unless the information is accompanied for substantial amount of genetic advance (Johnson *et al.,* 1955). High genotypic co-efficient of variation values for yield per plant, no. of fruits per plants, fruit length and fruit breadth and wider range of variation indicate more opportunity for selection of better genotype. In nature, bottle gourd exhibits great morphological and genetic variability and could wide environmental adaptation (Koffi, 2009).

In spite of being in cultivation since ancient times and the presence of the wide germplasm, conscious evaluation and exploitation of germplasm has not been attended to until recently. Bangladeshi farmers used different local cultivars and released (from different organization) bottle gourd variety. But their yield is not in satisfactory level. Varietal performance might be helpful to overcome this problem. Now a day's farmers are demanding for early maturing and high yielding variety of bottle gourd. To meet out the need of farmers, preliminary work should be initiated from identification of high yielding genotypes which can be utilized as variety or for further varietal development programme.

The specific objectives of the present study were as follows:

1. To find out the yield potentiality of different bottle gourd genotypes;
2. To study the association between the traits and direct and indirect effect of those traits on fruit yield per plant and
3. To screen out the suitable bottle gourd genotypes for future hybridization programme.

CHAPTER II
REVIEW OF LITERATURE

The review of literatures contain report on the crop under study and other related crops studied by several investigators, which appears pertinent in understanding the problem which may help in the explanation and the interpretation of results of the present study. Bottle gourd (*Lagenaria siceraria* L.) is an important vegetable cultivated in Bangladesh, but a few works have been done for the improvement of this crop in Bangladesh and other countries in the world. Many studies on the genetic variability, heritability, genetic advance, correlation, path co-efficient analysis of Bottle gourd have been executed by researchers in many countries of the world. Considering the studies, the review of literature is presented under the following heads:

2.1 Evaluation of genotypes

2.2 Genetic variability, Heritability, Genetic advance in Bottle gourd

2.3 Correlation analysis

2.4 Path co-efficient analysis

2.1 Evaluation of genotypes

Dubey *et al.* (2022) carried out an experiment and analysis of variance with twelve characters for thirty genotypes from the experiment were subjected to analysis of variance. Mean sum of squares due to genotypes were highly significant for all the characters (Table-2), indicating that there are significant differences among the genotypes with respect to the characters under study. The genotype NDBG-26 was recorded highest days to 1st pistillate flower anthesis 57.67 days and minimum (43.67 days) in case of NDBG-22. The genotype NDBG-32 was observed maximum fruit length (47.53 cm) and minimum in NDBG-66 (31.50 cm). The maximum fruit circumference was exhibited for NDBG-27 (34.50 cm) and minimum NDBG-60 (14.57 cm). The genotype NDBG-104 was recorded highest Vine length (6.61 m) and minimum in NDBG-22 (3.32 m). The highest fruit yield per plant (11.17 kg) was recorded with NDBG-32 and the lowest yield per plant (5.48 kg) was observed in NDBG-26. The genotypes mentioned above may serve as promising parents per donors for fruit yield and other characters for which they showed high performance.

Nkosi *et al.* (2022) found that wide variation exists in morpho-agronomic traits of the studied *Lagenaria siceraria* landraces and their F_1 progenies. It was observed that the F_1 offspring inherited either the male or female fruit morphological traits. For example, the cross between the DSI with dark green smooth isodiametric fruits and the RRP with green rough isodiametric fruits generated green rough isodiametric fruits of the RRP x DSI. F_1 progenies had superior performance than landraces in 15 quantitative traits (53.57%) out of the 28 evaluated traits. Although not statistically different, Cluster III genotypes (NSRC x DSI, NSRC x KSP, and RRP x DSI) out performed all genotypes with respect to high fruit yield, total fruit mass per plot, individual fruit mass, and large fruit width. Hence, these F_1 progenies can be used for further genetic improvement.

Yogananda *et al.* (2021) conducted an experiment to study the performance of bottle gourd genotypes. Among the genotypes, the BG-3 recorded the lower most node to fruit production (13.7) and highest fruit set percent (43.4%). BG-2 was earliest to 1st fruit harvest (57.8 days). IC 371745 recorded longer fruit length (68.8 cm) which was at par with IC 538142 (62.2 cm). Genotype IC417704 recorded maximum fruit diameter and flesh thickness (15.97 cm and 12.56 cm). Genotype IC 331101 recorded the lowest rind thickness (1.69 mm) and IC 536593 recorded the highest fruit weight (2.41 kg). Tvpm Local recorded highest no. of fruits per vine (6) followed by Pant Lauki-4 (4.3). The highest fruit yield was recorded in Tvpm Local (43.98 t ha^{-1}) with crop duration of 129.4 days. The highest TSS and ascorbic acid content were noted in the BG-3 (2.5^{0}B) and IC398545 (12.0 mg 100^{-1} g), respectively. Based on the mean yield performance of the genotypes and selection index score IC 536593, Tvpm Local and Pant lauki-4 were best performing genotypes.

Sohi *et al.* (2021) did a research experiment consists 17 hybrids of bottle gourd which are studied and replicated three times in a Randomized Complete Block Design in 7.5 $\times$ 3 m^2 plot size. It was found that the hybrid BG-HYB-18-2 gives best performance in terms of growth, quality and morphology of the experiment. The minimum days required to appearance of 1st male flowering (47.33). The minimum days required to appearance of 1st female flowering (56.66). The maximum no. of branches per vine (17.88), the maximum vine length (5.64 m). The maximum fruit weight (829.44 gm), the maximum no. of fruits per vine (9.77). The maximum yield per plant (8.10 kg), the maximum yield per hectare (360.15 quintal). The maximum Ascorbic Acid content

(34.11 mg/gm of fruit pulp). The Maximum TSS (4.17^0 Brix). The morphological identity was recorded by color (Light green and Creamy) and shape (Cylindrical and Oblong) of the fruit.

Kandasamy *et al.* (2019) conducted an experiment and it revealed that there were significant differences among the genotypes studied for all the characters except node no. of 1st male flower. On the basis of mean performance, among 20 genotypes LS12 was identified as the best genotypes as it has recorded higher mean values for six out of twelve characters studied.

Rambabu *et al.* (2017) held an experiment in bottle gourd with 21 genotypes in a Randomized Block Design with three replications. The morphological characterization was done as per minimal descriptors of NBPGR developed for bottle gourd. The results revealed that the greatest diversity was observed in fruit characters especially fruit shape and fruit color among the genotypes for various characters studied. Analysis of variance revealed significant differences among genotypes for all the characters. In general, PCV was marginally higher than the corresponding GCV indicated the less influence of environment in the expression of the characters under study.

Vaishali (2016), evaluated 10 genotypes of bottle gourd. Results revealed that the highest fruit yield per hectare was recorded in V3 (2013/ BOG VAR- 3). The maximum vine length was observed in V1 (2013/BOG VAR-1) and the minimum in (BBOG 15-3). The genotype V4 (2013/ BOG VAR-4) was the earliest in respect of node at which 1st female flower appeared and BBOG-15-3 produced the highest average fruit weight.

Sahu, L (2016), evaluated an experiment with 69 diverse genotypes of bottle gourd. The analysis of variance revealed that mean sum of squares due to genotypes were highly significant for all the characters, indicating the presence of variability in the genotype. The genotype IBG-61 was found highest yield and earliest flowering was noticed in IBG-69.

Shinde *et al.* (2014), experimented that the maximum no. of female flowers (36.63), no. of fruits per plant (10.80), yield per plant 6.85 kg) and yield per hectare (342.54 quintal) were recorded in variety Pusa Samridhi, while variety Local (v5) was observed maximum average weight of fruit (734.72 g).

Visen *et al.* (2014), evaluated genetic parameters between yield and yield contributing characters of different bottle gourd genotypes. Analysis of variance revealed significant variation among the genotypes for all tested characters. The highest fruit yield was found in genotype IBG-11 (536.66 q/ha) followed by IBG 25 (226.66 q/ha) and IBG 14 (223.26 q/ha).

Sahu *et al.* (2014), studied 8 varieties of bottle gourd and observed maximum fruit yield with variety Anokhi (592.90 q/ha) followed by variety Varad (579.84 q/h) and minimum yield (351.08 q/ha) in variety BGPL-4.

Uddin *et al.* (2014), experimented growth and yield performance of 11 bottle gourd lines. Maximum vine length (6.8 m), leaf area (975.4 cm^2), no. of fruits per plant (14.3), fruit length (54.9 cm), single fruit weight (1.43 kg), yield per plant (20.6 kg), yield per plot (82.0 kg) and yield per ha (50.1 ton) were found in L11, followed by L10. On the other hand, minimum sex ratio (male to female) (0.21), days to 1^{st} male flowering (37.3) and female flowering (41.0) was observed from L11.

Bhardwaj *et al.* (2013), studied 20 genotypes of bottle gourd and result revealed that the mean sum of squares due to replication was highly significant for all traits except fruit diameter, whereas the mean sum of squares due to genotype was highly significant for all the traits. GCV and PCV both were higher for vine length and no. of primary branches. No. of primary branches, vine length and yield per plant indicated that these traits can be improved through simple selection.

Thakur *et al.* (2013), evaluated 22 genotypes of bottle gourd and found that the genotype 2012 BOG VAR 4 was early (25 DAT) for days to 50% flowering including early male and female flowering i.e., 16.26 and 25.66 DAT. The genotype 2010 BOG VAR 3 exhibited early fruit setting (31.93 DAT) and also noted for early harvesting i.e. 41.33 DAT. Maximum no. of fruits per plant (14.83) was recorded in NDBG 104. Studies revealed that the genotypes 2012 BOG VAR 6, 2012 BOG VAR 4, 2011 BOG

VAR 3, 2010 BOG VAR 3 and NDBG 104 were observed to be promising for earliness and fruit yield.

Sharma and Sengupta (2013), studied 16 genotypes of bottle gourd and reported significant variation for all the characters among the genotypes. The significantly higher yield in Narendra Shivani (311.53 q/ha) might be due to higher values of yield attributes (fruit set percentage, fruit length, fruit width, no. of fruits per vine and fruit weight followed by Narendra Sanker Lauki. Whereas, the lower yield was observed in case of Narendra Jyoti (101.86 q/ha), respectively due to lower yield attributes. Among all the genotypes, Narendra Shivani, Narendra Sanker Lauki, and NS 421 gave promising results.

Kumar and Prasad (2011), experimented 5 hybrids and one open pollinated variety of bottle gourd. Among all the hybrids, Vikrant was found to be superior to the others in terms of fruit length, diameter, weight, yield, maximum net return per hectare and cost benefit ratio.

Kumar *et al.* (2011), studied 24 hybrids of bottle gourd obtained by crossing 11 parents and results revealed that the PCV was slightly higher than their corresponding GCV for all the characters studied. It was also observed that genotypic and phenotypic co-efficient of variation was higher for fruit yield per plant.

Husna *et al.* (2011), experimented 31 bottle gourd genotypes for different quantitative characters. Among all the genotypes G4, G31, G26 and G28 observed superior for fruit yield and selected for future breeding programme.

Mahato *et al.* (2010), experimented 15 lines of bottle gourd for different morphological characters, yield components and fruit yield. The genotypes varied in fruit colour (whitish to deep green with or without patches), shape (globular to elongated) and size. A good amount of variation was found in fruit length (10.42- 42.33 cm). The inbreeds, BCBG-17, BCBG-15, BCBG-33, BCBG-3 and BCBG-6 have emerged as highly promising for developing good quality hybrids.

2.2 Genetic variability, Heritability, Genetic advance

Dubey *et al.* (2022) carried out an experiment with 30 diverse genotypes of Bottle gourd. It is concluded that the PCV and GCV were high for no. of fruits per plant followed by fruit yield per plant. This indicates possibility of obtaining higher selection response in respect of these two traits for yield improvement. High heritability among with high genetic advance in percent of mean of genetic advance were recorded for node no. of 1^{st} staminate to pistillate flower appearance, vine length, average fruit weight, no. of fruits per plant and fruits yield per plant these six characters are provide very high selection response indicating that most likely, heritability was due to additive gene effects.

Lal *et al.* (2021), experimented an experiment on 17 characters in quantitative and two qualitative parameters of bottle gourd and reported that high heritability in narrow-sense was recorded by reducing sugar and total sugar in both years. Estimate of high genetic advance in percent of mean (>20%) was observed for node no. to 1^{st} female flower followed by primary branches per plant, total soluble solids and non-reducing sugar in both the years whereas node no. to 1^{st} female flower and vine length in y_1.

Rashid *et al.* (2020), conducted an experiment on bottle gourd. The experiment revealed significant differences among genotypes for all the traits. The estimates of phenotypic co-efficient of variance were slightly higher than the corresponding genotypic co-efficient of variance for all the characters studied indicating the little influence of environment. Fruit length, fruit diameter and total chlorophyll recorded high phenotypic and genotypic co-efficient of variation respectively, indicating that the genotypes had broad genetic base for these characters. High heritability coupled with high genetic advance (as percent of mean) was observed for fruit length, fruit diameter, total sugars and dry matter content indicating the preponderance of additive gene action.

Sultana *et al.* (2018) was studied to elucidate the genetic variability in thirty-nine genotypes of bottle gourd [*Lagenaria siceraria* (Mol.) Standl] in randomized complete block design with three replications. Observations were recorded for eleven quantitative characters viz., days to 1^{st} male flowering, days to 1^{st} female flowering, node no. of 1^{st} female flower, branches per plant, days to harvest, no. of fruits per plant, fruit weight, fruit length, fruit girth, 100 seed weight and yield ton per hectare. The analysis of variance showed highly significant differences for all the characters studied indicating considerable variability among the genotypes. The highest GCV (35.57%) and PCV (35.62%) were observed for fruit length. The differences between GCV and PCV were high for fruit no. per plant and days to 1st male flower open indicating environmental influences. High heritability associates with high estimates of genetic advance in percent of mean were noted for length of fruit, yield, girth of fruit and no. of fruits per plant indicating presence of additive gene effect and selection for these traits would be effective. Residual effects 0.067 imply that the total genotypic variability in yield has been explained by the characters associated in the study.

Rambabu *et al.* (2017) held an experiment in bottle gourd with 21 genotypes in a Randomized Complete Block Design with three replications and the result revealed high heritability coupled with high genetic advance as percentage of mean was observed for vine length, no. of primary branches, days to 1st male flowering, days to 1st female flowering, days to 1st harvest, no. of fruits per plant, average fruit weight, fruit length, fruit width, fruit yield per plant, sex ratio, no. of seeds per fruit, 100 seed weight, TSS of the pulp, total sugar content and ascorbic acid content of the pulp indicated that these characters were mainly controlled by additive gene effects and thus selection may be effective. Narayan (2013), experimented an experiment on 10 diverse genotype of bottle gourd and reported variability for fruit and seed characters viz., days to 50% germination, days to 1st male flower anthesis, days to 1st female flower anthesis, node no. of 1st male flower, node no. of 1st female flower, days to 1st fruit harvest, no. of branches per vine, vine length, fruit length, no. of fruits per vine, fruit yield per vine, no. of seeds per fruit and 100 seed mass.

Singh *et al.* (2008), conducted genetic variability in bottle gourd in both summer and rainy seasons and recorded the highest genotypic and phenotypic co-efficient of variation for yield per vine.

Gayen and Hossain (2006), conducted genetic variability and heritability of bottle gourd and observed that magnitude of phenotypic co-efficient of variation (PCV) was significantly higher than genotypic co-efficient of variation (GCV) for all the characters, it reflected the effect of environment on expression of these traits. The estimation of heritability ranged from 60.60 to 95.45%. High genetic advance as percentage of mean was recorded for sex ratio, fruit length, fruit yield per plant and

TSS. The sex ratio, fruit length, fruit yield per plant and TSS showed high heritability (above 80%) coupled with high genetic advance.

2.3 Correlation analysis

Dubey *et al.* (2022) carried out an experiment with 30 diverse genotypes of bottle gourd in Randomized Complete Block Design with three replications. The genotypic and phenotypic correlation co-efficient computed among the twelve characters under study in general, genotypic correlation co-efficient were found to be higher than the corresponding phenotypic correlation co-efficient, suggesting therefore, a strong inherent relationship in different pair of characters in bottle gourd germplasm. The result was concluded that fruit yield per plant (kg) exhibited highly significant and positive correlation with no. of fruits per plant, node no. to 1^{st} staminate flower, average fruit weight per fruit (kg), node no. to 1^{st} pistillate flower and fruit circumference (cm).

Kumari *et al.* (2021), evaluated an experiment with 9 diverse genotypes of bottle gourd. The results of correlation co-efficient analysis revealed that no. of fruits per vine highly significant and positively correlated with the no. of primary branches per vine whereas negatively correlated with days to 1^{st} harvest. The highest direct positive effect was exhibited by no. of fruits per vine followed by average fruit weight and fruit length while negligible positive direct effect was expressed by vine length, total no. of nodes per vine and no. of primary branches per vine.

Rehan *et al.* (2020), conducted performance of 24 genotypes of bottle gourd for evaluating the results of correlation co-efficient analysis and clearly indicates that the genotypic correlation co-efficient were found to higher than phenotypic correlation co-efficient for most of the characters, thus depicting a strong inherent association between various characters which are significantly affected by environmental components. Fruit yield per plant showed positive and highly significant correlation with no. of fruits per plant, days to 1^{st} fruit set which implies that these characters were the prime contributing factors to fruit yield. All the combination of traits should be considered while selecting a breeding programme for high yielding genotypes so that it is suitable for the breeders to identify improved and superior plant type.

Rashid *et al.* (2020), conducted an experiment on bottle gourd and correlation and path analysis among different characters of thirty bottle gourd genotypes were studied. Correlation studies indicated that characters viz., days to last fruit harvest, no. of fruits per plant and fruit yield per plant should be considered for improving quantitative traits in bottle gourd. Moreover, the traits like days to last fruit harvest and no. of fruits per plant showed significant positive genotypic correlation with fruit yield per plant indicating that direct selection of these traits will be effective.

Kunjam *et al.* (2019) conducted an experiment on nine genotypes of bottle gourd and the correlation analysis revealed that fruit yield showed the high positive and significant correlation with days to 1^{st} male flowering, fruit girth, vine length, no. of fruits per plant, average fruit weight and duration of crop. The path analysis revealed that positive and direct effect of fruit yield on average fruit weight, node no. at 1^{st} female flower, days to 1^{st} female flowering, node no. at 1^{st} male flower, 1^{st} fruit harvest and fruit girth. Hence, direct selection for these traits may lead to the development of high yielding genotypes of bottle gourd.

Mahapatra *et al.* (2019) did a study on bottle gourd. The study signified the correlation between 10 quantitative traits in 91 bottle gourd genotypes using correlation and path analysis. Results revealed that significant and positive correlation exists between the yield per plant with fruit diameter, average fruit weight and no. of fruits per plant. Significant negative correlation exists between fruit yield per plant with days to opening of 1^{st} female flower and days to 1^{st} fruit harvest.

A field experiment was conducted by Panigrahi *et al.* (2018) to assess the relationship between different morphological traits of bottle gourd by using 37 genotypes. The results revealed that there was significant positive correlation between different traits, which affects yield of the plant. The fruit yield per vine and per hectare had highly significant positive correlation with most of the characters viz., no. of primary branches, no. of fruits per vine, length of fruit, fruit yield per plant and vine length. Fruit yield per vine and yield per hectare were also positively correlated with each other. The best genotypes were found out on the basis of yield and it should be commercialized in national level.

Sultana *et al.* (2018) was studied to elucidate the correlation and path co-efficient analysis in thirty-nine genotypes of bottle gourd [*Lagenaria siceraria* (Mol.) Standl] in randomized complete block design with three replications. Correlation co-efficient at genotypic level were worked out among different characters keeping fruit yield ton per hectare as dependable variable. Yield was positively and significantly correlated with no. of branch per plant, fruit weight, 100 seed weight and fruits per plant. No. of fruits per plant recorded highest correlation (r=0.884) exhibited highly significant and positive correlation with yield. However, days to 1^{st} female flowering, days to 1^{st} male flowering, node no. of 1^{st} female flower, first harvest and length of fruit had negative non-significant correlation with fruit yield.

Sahu, L. (2016), investigated an experiment with 69 diverse genotypes of bottle gourd. The results of correlation co-efficient analysis revealed that fruit yield per plant was significantly and positive correlated with no. of branches per plant at both genotypic and phenotypic levels.

Janaranjani and Kanthaswamy (2015), investigated correlation studies with 18 different characters comprising of 36 hybrids of bottle gourd. The analysis revealed that fruit yield was positively and significantly correlated with fruit flesh thickness, no. of fruits per vine (0.92) and no. of fruit pickings.

Ara *et al.* (2014), investigated correlation studies on bottle gourd genotypes and reported correlation co-efficient was highest for nodal position of 1^{st} female flower opening followed by yield per plant, sex ratio among the genotypes. Total yield positively correlated with 1^{st} male flowering and female flowering, 1^{st} harvest, sex ratio, single fruit weight and fruit diameter. However, total yield was negatively correlated with edible maturity and fruit yield per plant in bottle gourd.

Sharma *et al.* (2013), conducted performance of 16 genotypes of bottle gourd for evaluating their performance for various horticultural characters. The significantly higher yield in Narendra Shivani (311.53 q/ha) might be due to higher values of yield attributes (fruit set percentage, fruit length, no. of fruits per vine, fruit weight and fruit width) followed by Narendra Sanker Lauki. High genotypic coefficient of variation (GCV) was observed for fruit weight (39.48%).

Emina *et al.* (2012), experimented 40 diverse genotypes of bottle gourd for correlation reported positive correlation of plant height with fruit length, seeds per plant and 100 seed mass but negative correlation with fruit weight.

Yadav and Kumar (2012) conducted that positive correlation was seen between length of fruit, weight per fruit, and no. of fruits per plant to the fruit yield per plant in bottle gourd.

Kamal *et al.* (2012) conducted that fruit yield per vine showed positive and significant correlation with no. of branches per vine, vine length, node no. of 1st male flower, node no. of 1st female flower, length of edible fruits, no. of fruits per vine, no. of seeds per fruit and 100 seed weight at genotypic and phenotypic levels in 10 diverse bottle gourd entries.

Pandit *et al.* (2009) evaluated 15 genotypes of bottle gourd revealed that the correlation between both genotypes and phenotypes indicated the overriding importance of fruit length and fruit width in determining the average fruit weight, which in turn adequately described the increase in fruit yield per plant.

2.4 Path co-efficient analysis

Dubey *et al.* (2022) carried out an experiment with 30 diverse genotypes with 12 characters of bottle gourd in Randomized Complete Block Design with three replications and path co-efficient analysis was found highest positive direct effect on fruit yield per plant was exerted by average fruit weight per fruit followed by fruits per plant, days to 1st fruit harvest, no. of primary branches per plant, days to 1st staminate flower anthesis, node no. to 1st staminate flowers and node no. to 1st pistillate flower.

Kumari *et al.* (2021), evaluated an experiment with 9 diverse genotypes of bottle gourd. The Path co-efficient analysis is representing direct and indirect contribution toward yield per plot along with residual effect. Data indicates that the no. of fruit per vine articulated maximum direct positive effect in the direction of yield per plot followed by fruit weight, no. of nodes per vine, vine length and no. of primary branches per vine followed by fruit length and fruit girth towards yield per plot.

Rehan *et al.* (2020), conducted performance of 24 genotypes of bottle gourd and the path co-efficient analysis showed highest positive direct effect on fruit yield for fruit weight, days to 1st fruit set, fruit girth and fruit length. By improving other characters fruit yield in bottle gourd can be improved.

Rashid *et al.* (2020), conducted an experiment on bottle gourd and correlation and path analysis among different characters of thirty bottle gourd genotypes were studied. Path co-efficient analysis revealed appreciable amount of direct positive effects of component traits like node no. at which 1st male flower appeared, days to anthesis of 1st female flower, days to last fruit harvest, no. of fruits per plant and total sugars on fruit yield per plant and should be given due importance by selection for breeding of new cultivars.

Kunjam *et al.* (2019) conducted an experiment on nine genotypes of bottle gourd and the path co-efficient analysis revealed that positive and direct effect of fruit yield on average fruit weight (2.96), node no. at 1st female flower (2.76), days to 1st female flowering (1.06), node no. at 1st male flower (1.37), first fruit harvest (0.60) and fruit girth (0.23). Fruit length, days to 1st male flowering, no. of branches, days to 50% flowering, duration of crop, no. of fruits per plant and fruit length showed negative and direct effects on fruit yield. In this analysis, fruit yield was taken as dependent variable and the rest of the characters were considered as independent variables.

Mahapatra *et al.* (2019) did a study on bottle gourd. The study signified the correlation between 10 quantitative traits in 91 bottle gourd genotypes using correlation and path analysis. Results revealed that the path co-efficient analysis of no. fruits per plant had maximum positive direct effect with marketable fruit yield per plant, followed by fruit diameter. There is no significant negative direct effect found on fruit yield per plant through any quantitative trait. This study demonstrated that selection for increased no. of fruits per plant, fruit diameter and average fruit weight may improve genetic gain in total fruit yield in bottle gourd breeding programme.

Sultana *et al.* (2018) was studied to elucidate the correlation and path co-efficient analysis in thirty nine genotypes of bottle gourd [*Lagenaria siceraria* (Mol.) Standl] in randomized complete block design with three replications. Path co-efficient analysis revealed that the highest positive direct effects on yield per hectare were exerted by no.

of fruits per plant (0.93) followed by fruit weight (0.467), 1st female flower open (0.011) and 100 seed weight (0.01). The contribution of yield components like 1st female flower open, 100 seed weight, fruit weight and no. of fruits per plant were high in the present study. The indirect effects of most of the characters were through no. of fruits per plant, no. of branches per plant and 100 seed weight will also be useful in bringing higher yield in bottle gourd.

Sahu, L. (2016), evaluated an experiment with 69 diverse genotypes of bottle gourd. The path co-efficient analysis revealed that no. of fruits per plant showed the highest positive direct effect on fruit yield followed by duration of crop, days to 1st female flower appears, no. of branches per plant, node no. of 1st female flower appears, 100 seed weight, node no. of 1st male flower appears, days to 1st female flower appears, whereas, average fruit weight, fruit girth, days to 1st fruit harvest, days to 50% flowering, fruit length and days to fruit set showed negative direct effects on fruit yield per plot.

Janaranjani *et al.* (2015), evaluated path analysis with 18 different characters comprising of 36 hybrids of bottle gourd. The path analysis indicated that no. of fruits per vine, days to 1st female flower opening (0.800), fruit cavity (0.380) and fruit weight (0.373) had positive direct effect on fruit yield, however fruit length (-0.370) recorded high negative direct effect on fruit yield per vine. No. of primary branches (-0.189), days to 1st male flower opening (1.103), sex ratio (0.141) and no. of pickings (-0.122) recorded negative low direct effect on fruit yield per vine.

Husna *et al.* (2011), conducted that the results of path co-efficient analysis revealed the maximum direct contribution towards yield per plant with no. of fruits per plant (0.680) followed by fruit weight (0.453) in 31 bottle gourd genotypes.

Yadav *et al.* (2007), studied on path co-efficient analysis in 18 bottle gourd strains and reported that all the characters except days to 1st female flowering, no. of nodes of 1st male flowering and fruit length had direct effect on yield. For indirect effects, the no. of fruits per plant showed highly significant and positive association with yield per plant due to days to 1st male flowering, no. of nodes of 1st female flowering, days to edible fruit, fruit width and no. of fruits per plant.

CHAPTER III
MATERIALS AND METHOD

The present investigation was carried out during Rabi season 2020 in the field of genetics and plant breeding at Sher-e-Bangla Agricultural University, Dhaka-1207. This chapter deals with a concise description of the locations of the experimental site, characteristics of soil, climate, materials and design of the experiment, land preparation, manuring and fertilizing, transplanting of seedlings, intercultural operations, harvesting, data recording procedure, economic and statistical analysis etc.

3.1 Experimental site

The study was conducted in the field of genetics and plant breeding at Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka-1207, during the period of 25^{th} October 2020 to March 2021.

3.2 Geographical location

The location of the experimental site was situated at 23^{o} 77' N latitude and 90^{o} 37' E longitudes with an elevation of 13.03 meters from the sea level. The experimental field belongs to the Agro-ecological zone of "The Modhupur Tract, AEZ-28”. Photograph showing experimental sites (Appendix I).

3.3 Climate of the experimental site

The experimental site was located in the subtropical climatic zone with wet summer and dry winter. Generally, very few rainfalls, moderate temperature and short-day length are observed during the Rabi season. The records of air temperature, humidity and rainfall during the period of experiment were noted from the Bangladesh Meteorological Department, Agargaon, Dhaka (Appendix III).

3.4 Characteristics of soil

The soil was clay loam in texture and olive gray with common fine to medium distinct dark yellowish-brown mottles. The selected plot was a medium high land. The pH of soil 4.47 to 5.63 while the amount organic carbon content, total N, available P and available K were 0.82%, 0.12%, 21 ppm and .27 mc per 100 gm of soil respectively. (Appendix II)

3.5 Genetic materials used for the experiment

The present study was performed with 10 genotypes of bottle gourd. Among the 10 genotypes, eight genotypes were collected from department of Genetics and Plant Breeding at Sher-e-Bangla Agricultural University (GEPB, SAU) and two genotypes were collected from local market (Table 1).

3.6 Design of the experimental site

The experiment was laid out in Randomized Complete Block Design (RCBD) with 3 replications having total area 225m^2. The genotypes were distributed into the pit of each block of the prepared layout of the experiment. Ten genotypes were assigned at random into pits in each replication. The distance maintained between pit to pit 3 m and block to block 3 m.

3.7 Polybag preparation and raising seedling

Due to uncertain rainfall during the period of the study, the seeds were dibbled in polybag for higher germination percentage and to get healthy seedlings. When the seedlings become 17 days old those were transplanted in the main field in the pit. Seeds were sown 25th October, 2020 before sowing seeds were treated with bavistin for 10 hrs. Plate 1 showing field preparation and raising of seedling in polybag.

3.8 Preparation of the experimental field

The experimental plot was prepared by several ploughing and cross ploughing followed by laddering and harrowing with tractor and power tiller to bring about good tilth in the first week of November, 2020. Weeds and other stables were removed carefully from the experimental plot and leveled properly. Preparation of land was displayed in Plate 2.

3.9 Pit preparation

The plots were raised 20 cm from the ground level. Pits of 50 x 50 x 50 cm size were prepared in each plot at a spacing of 3m from pit to pit.

Table 1. Name and source of collection of the 10 genotypes of bottle gourd

Genotypes	Name of the genotypes	Source of genotypes
G1	Ls-0001	GEPB, SAU
G2	Ls-0002	GEPB, SAU
G3	Ls-0003	GEPB, SAU
G4	Ls-0004	GEPB, SAU
G5	Ls-0005	GEPB, SAU
G6	Ls-0006	GEPB, SAU
G7	Ls-0007	GEPB, SAU
G8	Ls-0008	GEPB, SAU
G9	Hajari	Local Market
G10	Khet Lau	Local Market

Note:

GEPB= Genetics and Plant Breeding

SAU= Sher-e-Bangla Agricultural University

Plate 1. The pictorial view shows polybag preparation and raising seedlings

Plate 2. A pictorial view showing land preparation

3.10 Application of manure and fertilizers

Total cow dung, half of TSP and one third MOP were applied in the field during final land preparation. Remaining TSP and one third MOP and whole gypsum and zinc oxide and one third of urea were applied in pit one week prior to transplantation. Remaining urea and MOP were applied as top dressing in four installments at 20, 40, 60 and 75 days after transplanting. Doses of manure and fertilizers used in the study are shown in Table 2.

3.11 Transplanting of seedlings

Within 10 days germination of seeds was completed and the seedlings of different accessions were planted in the pit on 13th November, 2021. In each pit two seedlings were planted and the soil around the plant was firmly pressed by hand. After some days entresol were made and intercultural operation such as mulching, thinning, gap filling etc. were done. Field view of plants after transplanting of seedling during entresol making and field after weeding is presented in Plate 3.

3.12 Pesticide application

After transplanting in the main field, the young seedling was getting rotten. To overcome such kind of problem autistine mixed with water was sprayed at the base portion of the seedling. The bottle gourd seedlings were attacked by red pumpkin beetles at the seedling stage, which were controlled by hand killing and ripcord was sprayed in the field.

3.13 Harvesting

Fruits were harvested on the basis of horticultural maturity, size, color and age being determined for the purpose of consumption as the fruit grew rapidly and soon get beyond the marketable stage, frequent picking was done throughout the harvesting period. Fruits were picked with the sharp knife and care was taken to avoid injury of the vine.

Table 2. Doses of manure and fertilizers for the production of bottle gourd

Fertilizer	Recommended Doses
Cow dung	10 ton/ha
TSP	125 ton/ha
Urea	125 ton/ha
MOP	150 ton/ha
Gypsum	75 ton/ha
Zn fertilizer	10 ton/ha

A

B

Plate 3. The pictorial view showing preparation of entresol (A), field after weeding (B)

3.14 Data Collection

During the plant growth, one plant was selected from each pit for data collection. The sampling was done in such a way so that the border effects were completely avoided. For this purpose, the outer two lines and the extreme end of the middle rows were excluded (Plate 4). In order to study the genetic variability among the genotypes, the data were collected in respects of 19 parameters.

3.14.1 Leaf length (cm)

Leaf length (cm) was measured in five leaves in each genotype per replication and average data was recorded.

3.14.2 Leaf breadth (cm)

Leaf breadth (cm) was measured in five leaves in each genotype per replication and average data was recorded.

3.14.3 Leaf petiole length (cm)

Leaf petiole length (cm) was measured in five leaves in each genotype per replication and average data was recorded.

3.14.4 Internodes distance (cm)

Internodes distance (cm) was measured in five internodes in each genotype per replication and average data was recorded.

3.14.5 Days of 1st male flowering

The number of days required for 1st male flowering was counted for three replications separately and average data was recorded.

3.14.6 Days of 1st female flowering

The number of days required for 1st female flowering was counted for three replications separately and average data was recorded.

Plate 4. The pictorial view shows data observation and data collection

3.14.7 No. of male flowers per plant

The no. of male flowers per plant were counted for three replications separately and average data was recorded.

3.14.8 No. of female flowers per plant

The no. of female flowers per plant were counted for three replications separately and average data was recorded.

3.14.9 No. of fruits per plant

No. of fruits per plant was measured in total no. of fruits present in each genotype per replication and average data were recorded.

3.14.10 Fruit length (cm)

Fruit length (cm) was measured in five fruits in each genotype per replication and average data was recorded during fruit harvest for vegetable use.

3.14.11 Fruit diameter (cm)

Fruit diameter (cm) was measured in five fruits in each genotype per replication, then the average data was recorded during fruit harvest for vegetable use.

3.14.12 Fruit pedicel length (cm)

Fruit Pedicel length (cm) was measured in five fruits in each genotype per replication and average data was recorded.

3.14.13 Individual fruit weight (kg)

Individual fruit weight (kg) of three to five fruits in each germplasm during harvest for vegetable use was measured in kilogram.

3.14.14 No. of seeds per fruit

No. of seeds were observing by cutting three fruits of every genotype and data was recorded by observing the number of seeds per fruit.

3.14.15 100 seed weight (g)

100 seeds were weighed by electric balance in gram.

3.14.16 Seed length (cm)

Average lengths (cm) of three mature seeds of each genotype were measured by slide calipers and mean was calculated.

3.14.17 Seed breadth (cm)

Average breadth (cm) of three mature seeds of each genotype were measured in centimeter and mean was calculated.

3.14.18 Seed thickness (cm)

Three randomly selected seeds from selected plants of each genotype were measured for seed thickness (cm) and mean was calculated.

3.14.19 Fruit yield per plant (kg)

Weight of fruits (kg) of selected plants from each genotype was weighed and average data was recorded.

3.15 Statistical analysis

The data obtained for different characters were statistically analyzed by using Statistics 10 computer package program. The mean values of all the recorded characters were evaluated and analysis of variance was performed by the F- test. The significance of the difference among the treatment combinations of means was estimated by Duncan's Multiple Range Test (DMRT) at 5% level of probability (Gomez and Gomez, 1984).

3.15.1 Estimation of genetic parameters

The genetic parameters such as genotypic co-efficient of variation (GCV), phenotypic co-efficient of variation (PCV), heritability in broad sense and genetic advance for different characters were worked out by following the standard procedures for all the genotypes under study.

3.15.2 Analysis of variance (ANOVA)

Data were analyzed by the methods outlined by Panse and Sukhatme (1978) using the mean values of random plants in each replication from all genotypes to find out the significance of genotypes effect. The data for different characters were statistically analyzed on the basis of the model suggested by Cochran and Cox (1957).

$Yij = \mu + bi + tj + eij$

3.15.3 Estimation of genotypic and phenotypic variances:

Formula given by Chaudhary and Prasad (1968) was used to calculate phenotypic and genotypic variance.

Genotypic variance (σ^2_g) = (TMSS – EMSS) / R

Error variance = σ^2_e

Phenotypic variance = $\sigma^2_p = \sigma^2_g + \sigma^2_e$

Where, TMSS is treatment mean sum of square

EMSS is error mean sum of square

R is number of replications

3.15.4 Estimation of genotypic and phenotypic co-efficient of variation (GCV and PCV)

They are expressed as percentage according to Burton, G.W (1952).

Genotypic co-efficient of variation (GCV) = $(\sigma_g/\overline{X}) \times 100$

Phenotypic co-efficient of variation (PCV) = $(\sigma_p/\overline{X}) \times 100$

Where, σ_g = Genotypic standard deviation

σ_p = Phenotypic standard deviation

$\overline{X}$= General mean of the trait

As indicated by Sivasubramanjan and Menon (1973), GCV and PCV are categorized as follows: 0 – 10 %: Low; 10 – 20 %: Moderate; >20 %: High

3.15.5 Estimation of broad sense heritability (h^2_b)

Hanson *et al.* (1956) estimated broad sense heritability as the ratio of genotypic variance (Vg) to the phenotypic variance (Vp) and expressed in percentage.

Broad sense heritability (h^2_b) = (V_g /V_p)

Robinson *et al.* (1949) categorized broad sense heritability as follows:

0 – 0.30: Low; 0.30 – 0.60: Moderate; > 0.60: High

3.15.6 Estimation of genetic advance (GA)

It was calculated by using the following formula given by Robinson *et al*. (1949).

$GA = i. \sigma_p. h^2_b$

Where, i = Efficacy of selection (2.06 at 5% selection intensity)

σ_p = Phenotypic standard deviation

h^2_b = Broad Sense Heritability

3.15.7 Estimation of genetic advance as percent of means (GAM)

GA as percent of mean (GAM) = $(GA/\overline{X}) \times 100$

GA = Genetic advance;

$\overline{X}$ =General mean of the trait

Johnson *et al*. (1955) categorized GAM as follows:

0 - 10 %: Low; 10 -20 %: Moderate; > 20 %: High

3.15.8 Estimation of genotypic and phenotypic correlation co-efficient

For calculating the genotypic and phenotypic correlation coefficient in all possible combination the formula suggested by Johnson *et al*. (1955) and Hanson *et al.* (1956) were adopted. The genotypic covariance components between two traits and of the phenotypic covariance component were derived in the same way as for the corresponding variance components. The covariance components were used to compute genotypic and phenotypic correlation between the pairs of the characters as follows:

Genotypic correlation $=\sigma^2_{gxy}/\sqrt{\sigma^2_{gx}+\sigma^2_{gy}}$

Where, σ^2_{gxy}= Genotypic covariance between the traits x and y.

σ^2_{gx}= Genotypic variance of the trait x

σ^2_{gy}= Genotypic variance of the trait y

Thus, Phenotypic correlation (r_{phxy}) $=\sigma^2_{phxy}/\sqrt{\sigma^2_{phx}+\sigma^2_{phy}}$

Where, σ^2_{phxy}= Phenotypic covariance between the traits x and y.

σ^2_{phx}= Phenotypic variance of the trait x

σ^2_{phy}= Phenotypic variance of the trait y

3.15.9 Path co-efficient analysis

Path co-efficient analysis was done according to the procedure employed by Dewey and Lu (1959) and Dabholkar (1992), using simple correlation values. In path analysis, correlation co-efficient was partitioned into direct and indirect effects of independent variables on the dependent variable.

In order to estimate direct and indirect effect of the correlated characters, say x_1, x_2, and x_3 yield y, a set of simultaneous equations (three equations in this example) is required to be formulated as shown below:

$r_{yx1}= P_{yx1}+ P_{yx2rx1x2}+P_{yx3rx1x3}$

$r_{yx2}= P_{yx1rx1x3}+ P_{yx2}+ P_{yx3rx2x3}$

$r_{yx3}= P_{yx1rx1x3}+ P_{yx2rx2x3}+ P_{yx3}$

P_{yx1}= the direct effect of x_1 on y

$P_{yx2rx1x2}$=the indirect effect of x_1 via x_2 on y

$P_{yx3rx1x3}$= the indirect effect of x_1 via x_3 on y

After calculating the direct effect and indirect effect of the characters, residual effect (R) was calculated by using the formula given below:

$P^2R_Y= 1-\Sigma P_{iy}.r_{iy}$, Where, $P^2R_Y= (R^2)$ and hence residual effect, $R= (P^2R_Y)$ 1/2

P_{iy}= direct effect of the character on yield, r_{iy}= correlation of the character with yield

CHAPTER IV

RESULTS AND DISCUSSION

The experiment was done for characterization of 10 bottle gourd genotypes through comparatively their morphological and yield and yield contributing characters performance. The research was also conducted to find out the phenotypic, genotypic and environmental variance, phenotypic and genotypic co-efficient of variation, heritability, genetic advance, genetic advance in percent of mean, correlation co-efficient and path co-efficient to estimate direct and indirect effect of yield contributing traits on fruit yield per plant. The recorded data depend on various characters such as leaf length (cm), leaf breadth (cm), leaf petiole length (cm), internodes distance (cm), days to 1st male flowering, days to 1st female flowering, no. of male flowers, no. of female flowers, no. of fruit per plant, fruit length (cm), fruit diameter (cm), length of petiole (cm), individual fruit weight (kg), no. of seeds per fruit, 100 seed weight (g), seed length (cm), seed breadth (cm), seed thickness (cm) and fruit yield per plant (kg) of 10 genotypes of bottle gourd. The data were statistically analyzed and thus acquired results are described below under the following headings:

4.1 Characterization

4.2 Genetic variability

4.3 Heritability, genetic advance and genetic advance in percentage of mean

4.4 Correlation co-efficient analysis

4.5 Path co-efficient analysis

4.1 Characterization of Bottle gourd

4.1.1 Fruit color

Fruit color is one of the important traits in bottle gourd for consumer preference marketing. Generally light green, green, dark green and whitish color fruits are commonly found in the market. In the present study, fruit color was classified in distinct groups like light green, dark green and white. Among the ten genotypes, six genotypes (G1, G3, G5, G6, G9 and G10) produced dark green fruit, two genotypes (G4 and G7) produced light green fruits and two genotypes (G2, G8) produced white fruit (Table 3 and Plate 5).

4.1.2 Fruit shape

Fruit shape is an important feature for marketing. In the present study various types of bottle gourd were found. From the ten genotypes oblong, elongate and round shaped were observed. The genotypes G1, G4 and G7 were oblong shaped fruits, G2, G3, G6, G9 and G10 produced elongate shaped fruits and G5, G8 were round shaped fruits (Table 3 and Plate 5).

4.1.3 Seed color

Dark brown, light brown, black and white color seeds are commonly found in bottle gourd. In the present study light brown, dark brown and white colored seed were observed. Genotypes G1, G3, G7 produced light brown seed; G6, G9, G10 produced dark brown seed and white seeds were produced by G2, G4, G5, G8 (Table 3). A pictorial view of seed color and seed shape is presented in Plate 6.

4.2 Genetic variability, heritability, genetic advance and genetic advance in percentage of mean

For conducting a successful breeding program, estimating genetic variability for the selected traits is important. The available variability can be partitioned into different genetic parameters viz, co-efficient of variation, genetic heritability and genetic advance that can be acted as a basis for selection. Analysis of variance revealed significant variation existed among the selected traits. The mean performance of bottle gourd for the characters associated with yield performance are described as follows:

4.2.1 Leaf length (cm)

The estimated data revealed that the maximum leaf length (cm) was observed in G1(20.49 cm) followed by G9 (20.38 cm) and minimum was recorded in G4 (17.97) followed by G2(19.07) with mean value of 19.58 (Table 5). The phenotypic variance (0.98) appeared to be slightly higher than genotypic variance (0.43) suggested that less influence of environment on the expression and phenotypic co-efficient of variation (PCV) were higher (5.04) than the genotypic co-efficient of variation (GCV) (3.35) indicating that they all interacted with the environment to some extent. Karmokar (2015) got that the phenotypic variance appeared to be slightly higher than genotypic variance suggested that less influence of environment on the expression of this gene controlling this trait. Moderate heritability (44.12%), low genetic advance (.90) along

Table 3. Characterization of 10 bottle gourd genotypes

No. of Genotype	Fruit Color	Fruit Shape	Seed Color
G1	Dark Green	Oblong	Light Brown
G2	White	Elongate	White
G3	Dark Green	Elongate	Light Brown
G4	Light Green	Oblong	White
G5	Dark Green	Round	White
G6	Dark green	Elongate	Dark Brown
G7	Light Green	Oblong	Light Brown
G8	White	Round	White
G9	Dark Green	Elongate	Dark Brown
G10	Dark Green	Elongate	Dark Brown

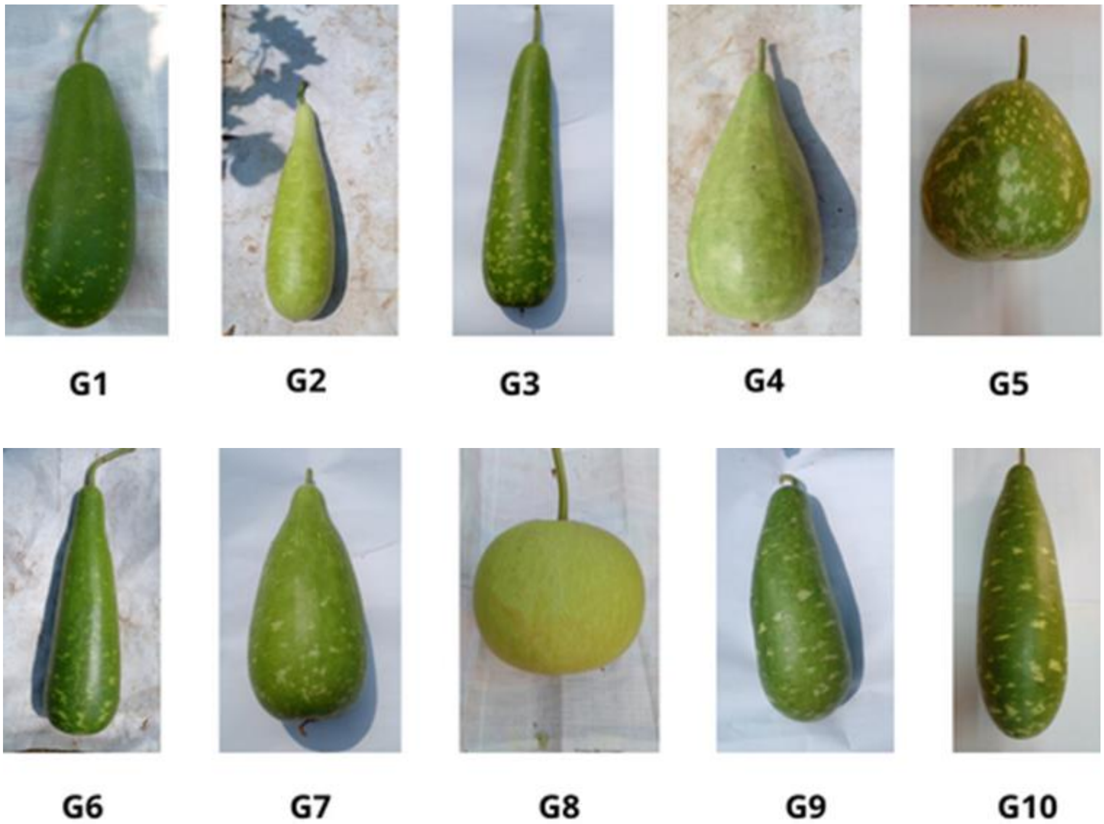

Plate 5. A pictorial view showing fruit color and fruit shape

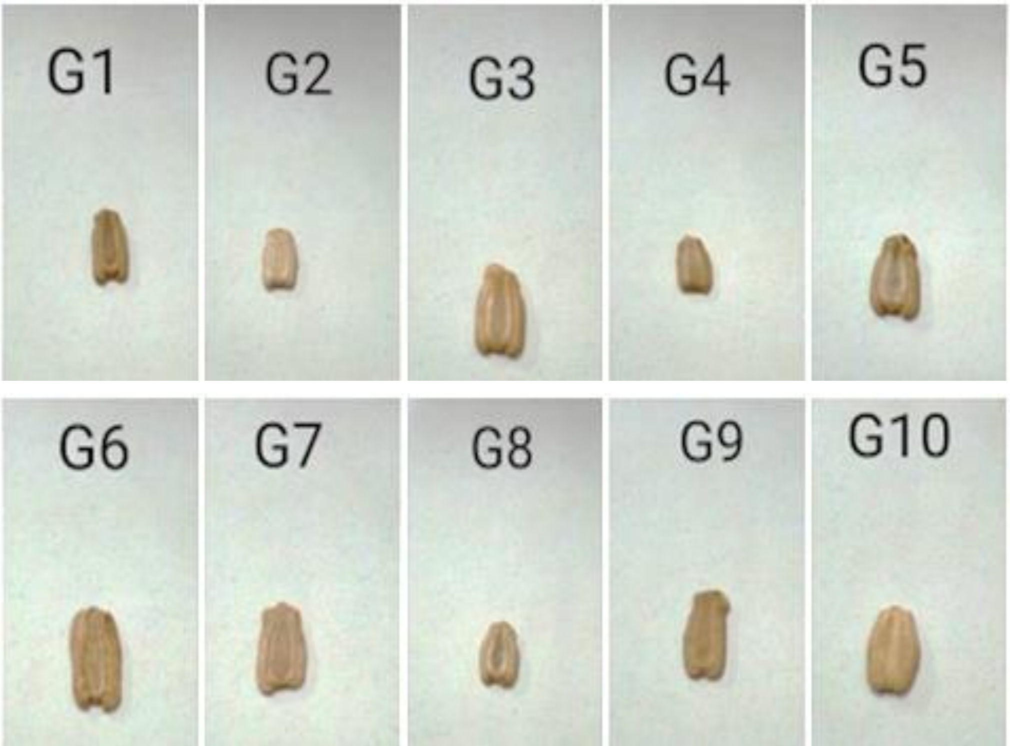

Plate 6. A pictorial view showing seeds color and shape

with low genetic advance as percent mean (4.59%) were noted for leaf length, mostly controlled by non-additive genes. This suggested the scope of improvement through selection is ineffective. Sharma *et al.* (2013) found the same findings for moderate heritability in bottle gourd.

4.2.2 Leaf breadth (cm)

The maximum leaf breadth (cm) was in G5 (28.83 cm) followed by G6 (25.37 cm) and minimum was in G8 (23.87 cm) followed by G1 (23.90) and G2 (23.90) with mean value 25.16 (Table 5). The phenotypic variance (3.06) appeared to be slightly higher than genotypic variance (1.83) suggested that less influence of environment on the expression of this gene controlling this trait (Table 5). The phenotypic co-efficient of variation was higher (7.02%) than the genotypic co-efficient of variation (5.42%) indicating that they all interacted with the environment to some extent. Husna (2011) also found GCV was lower than PCV for this character in bottle gourd. Moderate heritability (59.61%), low genetic advance (2.15) along with low genetic advance as percent mean (8.62%) (Table 6) indicating leaf breadth, mostly controlled by non-additive genes action. This suggested that due to the presence of non-additive type of gene action, the selection may not be effective. Similar results were also reported by Rambabu *et al.* (2017) and Maurya *et al.* (2019).

4.2.3 Leaf petiole length (cm)

Maximum leaf petiole length (cm) was observed in G5 (15 cm) followed by 13.50 cm in G6 (13.50 cm) and minimum was found in G2 (10.17) followed by G3 (10.83) with mean value 12.18 (Table 5). The phenotypic variance (2.88) appeared to be slightly higher than genotypic variance (1.51) (Table 6). The phenotypic variance appeared to be higher than the genotypic variance suggested considerable influence of environment on the expression of the genes controlling leaf petiole length. The phenotypic co-efficient of variation (14.03%) were higher than the genotypic co-efficient of variation (10.17%) (Table 6) for this trait suggested the considerable possibility of yield improvement through selection. Karmokar (2015) also found that the phenotypic variance was higher than the genotypic co-efficient of variation. Moderate heritability (52.50%), low genetic advance (1.84) along with moderate genetic advance as per cent mean (15.18%) (Table 6). Moderate heritability coupled with moderate genetic advance as percent mean mostly controlled by additive and non-additive genes. This suggested that transmission genes related to this trait to further generation possible. Similar results were reported by Islam *et al.* (2009) in bitter gourd.

4.2.4 Internodes distance (cm)

The estimated data revealed that the maximum internodes distance was observed in G5 (18.10) followed by G9 (17.43) and minimum was recorded in G1 (13.63) followed by in G10 (15.23) with mean value 16.07 (Table 5). The difference between phenotypic variance (2.60) and genotypic variance (1.01) was slightly higher indicating less influence of environment on this character. Phenotypic co-efficient of variation (PCV) was higher (10%) than the genotypic coefficient of variation (GCV) (6.24%) for the trait indicating that they all interacted with the environment to some extent. The low value of genotypic co-efficient of variation (GCV) for the trait suggested that yield improvement through selection of this trait may not be possible. Rabbi (2020) was observed the same result in his study. Low heritability (38.97%), low genetic advance (1.29) along with low genetic advance as percent mean (8.03%) (Table 6) indicated that this trait mostly controlled by non-additive genes. This suggested that the scope of improvement through selection would not be effective. The same results were supported to the findings of Sravani *et al.* (2021) and Durga et al. (2021) in ridge gourd.

4.2.5 Days to 1st male flowering

The maximum duration was observed in G7 (60 days) followed by G3 (52.67 days) and the minimum duration was in G10 (43.67 days) followed by in G1 (47 days) with mean value 50.78 (Table 5). Mean performance of days to 1st male flowering in 10 genotypes is presented in Figure 1. The difference between phenotypic variance (21.54) and genotypic variance (16.93) indicating the slight environmental effect (Table 6). Phenotypic co-efficient of variation (PCV) was higher (9.18%) than the genotypic co-efficient of variation (GCV) (8.14%) of the trait indicating that they all interacted with the environment to some extent. Sultana *et al.* (2018) also found the same result as highly significant among the genotypes. High heritability coupled with moderate genetic advance in percent of mean indicating the role of both additive genes and non-additive genes in governing this trait. In majority of the crosses for this trait revealed that direct selection but to a limited extent improving this trait. Similar results were reported by Kandasamy *et al*. (2019) and Rashid *et al*. (2020b) in bottle gourd.

Table 4. Analysis of variance for different morphological characters of 10 bottle gourd genotypes

Source of variance	df	LL	LB	LPL	ID	DFMF	DFFF	NMFP	NFFP	NFP
Replication	2	0.02	2.66	0.93	0.51	0.83	1.63	3.10	14.63	1.63
Genotype	9	1.85*	6.71**	5.91**	4.62*	55.41**	55.26**	37.13**	10.74**	7.33**
Error	18	0.55	1.24	1.37	1.59	4.61	2.04	5.36	3.08	1.30

Table 4 (contd.). Analysis of variance for different morphological plant characters of 10 bottle gourd genotypes

Source of variance	df	FL	FD	FPL	IFW	NSPF	HSW	SL	SB	ST	FYPP
Replication	2	1.43	1.40	0.32	0.03	79.30	2.96	0.04	0.01	0.001	8.61
Genotype	9	127.07**	273.46**	4.84**	1.01**	14462.10**	16.72**	0.11**	0.03**	0.002**	81.58**
Error	18	0.58	0.57	0.21	0.03	143.90	1.80	0.01	0.001	0.001	5.34

* Indicates significant at 0.05 probability level, ** indicates significant at 0.01 probability level

LL=Leaf length (cm), LB=Leaf breadth (cm), LPL=Leaf petiole length (cm), ID=Internodes distance (cm), DFMF=Days of 1st male flowering, DFFF=Days to 1st female flowering, NMFP =No. of male flowers per plant, NFFP=No. of female flowers per plant, NFP=No. of fruit per plant, FL=Fruit length (cm), FD=Fruit diameter (cm), FPL=Fruit pedicel length (cm), IFW=Individual fruit weight (kg), NSPF =No. of seeds per fruit, HSW=100 seed weight (g), SL=Seed length (cm), SB=Seed breadth (cm), ST=Seed thickness (cm) and FYPP=Fruit yield per plant (kg)

Table 5. Mean performance of 10 bottle gourd genotypes based on different morphological traits related to yield

Genotypes	LL	LB	LPL	ID	DFMF	DFFF	NMFP	NFFP	NFP	FL
G1	20.49a	23.90b	12.83bc	13.63d	47.00ef	50.67bc	40.67bc	15.00bcd	10.00c	32.97c
G2	19.07cd	23.90b	10.17d	16.22abc	52.33bc	53.00b	39.67bc	15.00bcd	10.33bc	39.07b
G3	20.17abc	24.57b	10.83cd	16.80abc	52.67b	53.00b	47.67a	17.33ab	12.00ab	42.23a
G4	17.97d	24.67b	12.17bcd	15.78bcd	48.67cde	52.00bc	37.67c	12.00d	8.67c	38.67b
G5	20.13abc	28.83a	15.00a	18.10a	51.33bcd	50.33c	37.67c	14.00cd	10.00c	30.10d
G6	19.49abc	25.37b	13.50ab	15.53bcd	48.33de	51.33bc	41.67b	16.33abc	12.67a	42.30a
G7	20.21abc	25.27b	12.00bcd	16.59abc	60.00a	61.33a	38.33bc	15.00bcd	9.00c	34.07c
G8	19.53abc	23.87b	11.00cd	15.83bc	51.00bcd	50.33c	46.33a	19.00a	12.67a	21.77e
G9	20.38ab	25.01b	11.67bcd	17.43ab	50.67bcde	52.00bc	38.67bc	16.33abc	9.00c	38.53b
G10	19.11bcd	23.87b	11.83bcd	15.23cd	43.67f	43.67d	39.67bc	15.67bc	9.00c	41.43a
LSD (0.05)	1.27	1.91	2.01	2.16	3.68	2.45	3.97	3.01	1.96	1.30
SD	0.96	1.74	1.66	1.57	4.49	4.30	3.88	2.50	1.79	6.32
SE (±)	0.61	0.91	0.96	1.03	1.75	1.17	1.89	1.43	0.93	0.62
Min	17.97	23.87	10.17	13.63	43.67	43.67	37.67	12.00	8.67	21.77
Max	20.49	28.83	15.00	18.10	60.00	61.33	47.67	19.00	12.67	42.30
Mean	19.58	25.16	12.18	16.07	50.78	51.89	41.11	15.56	10.39	35.43
CV (%)	3.77	4.46	9.67	7.81	4.25	2.76	5.67	11.27	11.03	2.11

Table 5 (Contd.). Mean performance of 10 bottle gourd varieties based on different morphological traits related to yield

Genotypes	FD	FPL	IFW	NSPF	HSW	SL	SB	ST	FYPP
G1	31.30f	12.57a	1.02e	309.67e	16.47bcd	1.47e	0.68bcd	0.18abc	10.22d
G2	27.87g	12.10ab	0.95e	362.33d	14.57de	1.30f	0.63d	0.21ab	9.84d
G3	32.03f	8.67e	1.22de	394.53c	16.93bc	1.8967a	0.72b	0.17cd	14.71c
G4	48.07b	10.80c	2.33ab	420.93b	18.43ab	1.41ef	0.70bc	0.18bc	20.07b
G5	54.09a	12.10ab	2.62a	306.30e	20.50a	1.80ab	0.82a	0.22a	26.31a
G6	32.53f	11.60b	1.64c	441.73a	20.167a	1.70bc	0.72b	0.19abc	20.67b
G7	44.10c	9.90d	2.17b	420.30b	16.13cd	1.64cd	0.80a	0.21ab	19.53b
G8	53.67a	9.87d	1.51cd	220.47f	12.70e	1.45ef	0.52e	0.13d	19.15b
G9	36.82e	9.80d	1.44cd	401.93bc	16.40bcd	1.71bc	0.65cd	0.21ab	12.91cd
G10	39.00d	10.43cd	2.15b	407.40bc	17.20bc	1.50de	0.81a	0.19abc	19.35b
LSD (0.05)	1.29	0.78	0.30	20.58	2.30	0.15	0.06	0.04	3.96
SD	9.24	1.28	0.58	67.70	2.55	0.20	0.10	0.03	5.41
SE (±)	0.62	0.37	0.14	9.79	1.09	0.07	0.03	0.02	1.89
Min	27.87	8.67	0.95	220.47	12.70	1.30	0.52	0.13	9.84
Max	54.09	12.57	2.62	441.73	20.50	1.90	0.82	0.22	26.31
Mean	40.12	10.76	1.72	362.32	16.89	1.59	0.70	0.19	17.41
CV (%)	1.89	4.21	10.14	3.25	7.91	5.64	5.15	12.14	13.37

LL=Leaf length (cm), LB=Leaf breadth (cm), LPL=Leaf petiole length (cm), ID=Internodes distance (cm), DFMF=Days of 1st male flowering, DFFF=Days of 1st female flowering, NMFP =No. of male flowers per plant, NFFP=No. of female flowers per plant, NFP=No. of fruits per plant, FL=Fruit length (cm), FD=Fruit diameter (cm), FPL=Fruit pedicel length (cm), IFW=Individual fruit weight (kg), NSPF =No. of seeds per fruit, HSW=100 seed weight (g), SL=Seed length (cm), SB=Seed breadth (cm), ST=Seed thickness (cm) and FYPP=Fruit yield per plant (kg)

Table 6. Estimation of genetic parameters for morphological characters related to yield

Characters	Phenotypic variance	Genotypic variance	PCV (%)	GCV (%)	Heritability (%)	GA	GA (%)
LL	0.98	0.43	5.04	3.35	44.12	0.90	4.59
LB	3.06	1.83	7.02	5.42	59.61	2.15	8.62
LPL	2.88	1.51	14.03	10.17	52.50	1.84	15.18
ID	2.60	1.01	10.00	6.24	38.97	1.29	8.03
DFMF	21.54	16.93	9.18	8.14	78.60	7.52	14.86
DFFF	19.78	17.74	8.59	8.14	89.68	8.22	15.87
NMFP	15.95	10.59	9.79	7.98	66.40	5.46	13.39
NFFP	5.63	2.56	15.25	10.27	45.36	2.22	14.25
NFP	3.31	2.01	17.61	13.72	60.74	2.28	22.03
FL	42.74	42.16	18.10	17.98	98.65	13.29	36.79
FD	91.53	90.96	23.95	23.87	99.38	19.59	49.03
FPL	1.75	1.54	12.26	11.52	88.23	2.40	22.29
IFW	0.36	0.33	35.06	33.56	91.63	1.13	66.19
NSPF	4916.63	4772.73	19.03	18.74	97.07	140.22	38.04
HSW	6.77	4.97	15.35	13.16	73.46	3.94	23.23
SL	0.04	0.03	12.89	11.59	80.85	0.34	21.47
SB	0.01	0.01	13.91	12.92	86.25	0.17	24.72
ST	0.0005	0.0004	16.82	11.64	47.90	0.03	16.60
FYPP	30.75	25.41	32.10	29.18	82.64	9.44	54.65

LL=Leaf length (cm), LB=Leaf breadth (cm), LPL=Leaf petiole length (cm), ID=Internodes distance (cm), DFMF=Days of 1st male flowering, DFFF=Days of 1st female flowering, NMFP =No. of male flowers per plant, NFFP=No. of female flowers per plant, NFP=No. of fruits per plant, FL=Fruit length (cm), FD=Fruit diameter (cm), FPL=Fruit pedicel length (cm), IFW=Individual fruit weight (kg), NSPF =No. of seeds per fruit, HSW=100 seed weight (g), SL=Seed length (cm), SB=Seed breadth (cm), ST=Seed thickness (cm) and FYPP=Fruit yield per plant (kg)

PCV= Phenotypic coefficient of variation, GCV= Genotypic co-efficient of variation, GA= Genetic advance, GA (%) = Genetic advance in the percentage of mean

4.2.6 Days to 1st female flowering

The estimated data revealed that the maximum duration was observed in G7 (61.33 days) followed by G2 and G3 (days) and the minimum duration was in G10 (43.67 days) followed by G5 and G8 (50.33 days) with mean value 51.89 (Table 5). Mean performance of days to 1st female flowering in 10 genotypes is presented in Figure 1. The difference between phenotypic variance (19.78) and genotypic variance (17.74) was with less environmental influence (Table 6). Phenotypic variance was higher than the genotypic variances for this trait, that indicated the influences of environmental factor on this trait. Sultana *et al.* (2018) observed the same range of variations among the genotypes and it was highly significant. High heritability coupled with moderate genetic advance in percent of mean was obtained for indicating the action of both additive genes and non-additive genes for this trait. The scope of improvement through selection may be possible. Similar results were reported by Damor *et al.* (2016), Deepthi *et al.* (2016) and Kumar et al. (2018).

4.2.7 No. of male flowers per plant

It was observed that the maximum no. of male flowers per plant were observed in G3 (47.67), followed by G8 (46.33) and the minimum no. of flowers were in G4 and G5 (37.67) followed by G7 (38.33) with mean value 41.11 (Table 5 and Plate 7). Mean performance of no. of male flowers per plant in 10 genotypes is presented in Figure 2. The difference between phenotypic variance (15.95) and genotypic variance (10.59) was with less environmental influence. Phenotypic variance was higher than the genotypic variances of the trait (Table 6) thus indicated the moderate influence of environmental factor on this trait. High heritability coupled with moderate genetic advance in percent of mean was observed in all crosses indicating the predominance of both additive genes and non-additive genes for this trait. As a whole this indicated the possibility of selecting genotypes for this trait. Same results were supported by the findings reported by Rana and Pandit (2011), Rabbani *et al*. (2012) for various cucurbits.

4.2.8 No. of female flowers per plant

The estimated data revealed that the maximum no. of female flowers per plant were observed in G8 (19), followed by G3 (17.33) and the minimum no. of female flowers

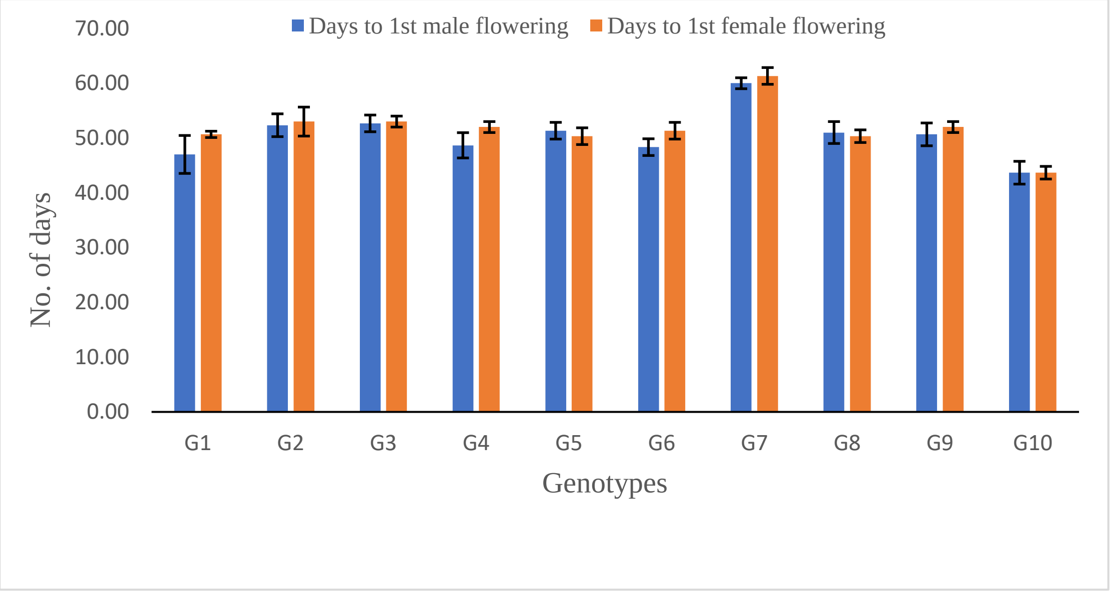

Figure 1. Mean performance of days to 1st male flowering and days to 1st female flowering in 10 genotype of bottle gourd

were in G4 (12) followed by G5 (14) with mean value 15.56 (Table 5 and Plate 7). Mean performance of no. of female flowers per plant in 10 genotypes is presented in Figure 2. The difference between phenotypic variance (5.63) and genotypic variance (2.56) was with little environmental influence. Phenotypic co-efficient of variation (PCV) were higher than the genotypic co-efficient of variation (GCV) for the trait (Table 6) indicating that they all interacted with the environment to some extent. Moderate heritability (45.36%), low genetic advance (2.22) along with moderate genetic advance as per cent mean (14.25%) (Table 6). Moderate heritability coupled with moderate genetic advance as percent of mean was obtained for indicating mostly controlled by additive genes and non-additive genes. The scope of improvement using selection will be effective. The findings were supported by Kumar *et al.* (2013) and Deepa and Mariappan (2013) for various cucurbits.

4.2.9 No. of fruits per plant

It was observed that the maximum no. of fruits per plant was recorded in G6, G8 (12.67) followed by G3 (12) and the minimum no. was in G4 (8.67) followed by G7, G9, G10 (9) with mean value 10.39 (Table 5). The difference between phenotypic variance (3.31) and genotypic variance (2.01) indicating slight environmental influence. The phenotypic co-efficient of variation was higher than the genotypic co-efficient of variation (Table 6). The medium value of genotypic co-efficient of variation (GCV) for the trait suggested the moderate possibility of yield improvement through selection of this trait. Dubey *et al.* (2022), Sultana *et al.* (2018) and Rambabu *et al.* (2017) was observed similar results on this character. High heritability of 60.74% with low genetic advance (2.28) was noted for the character and the value of genetic advance in percent of mean was high (22.03%) (Table 6) was obtained for indicating this trait was no. of fruits per plant, mostly controlled by additive genes. This suggested that the scope of improvement through selection may be effective. The result was similar with the findings of Rashid *et al.* (2020a) in bottle gourd.

4.2.10 Fruit length (cm)

The maximum fruit length was recorded in G6 (42.30 cm) followed by G3 (42.23 cm) and the minimum number was G8 (21.77) followed by G5 (30.10) with mean value 35.43 (Table 5). The difference between phenotypic variance (42.74) and genotypic

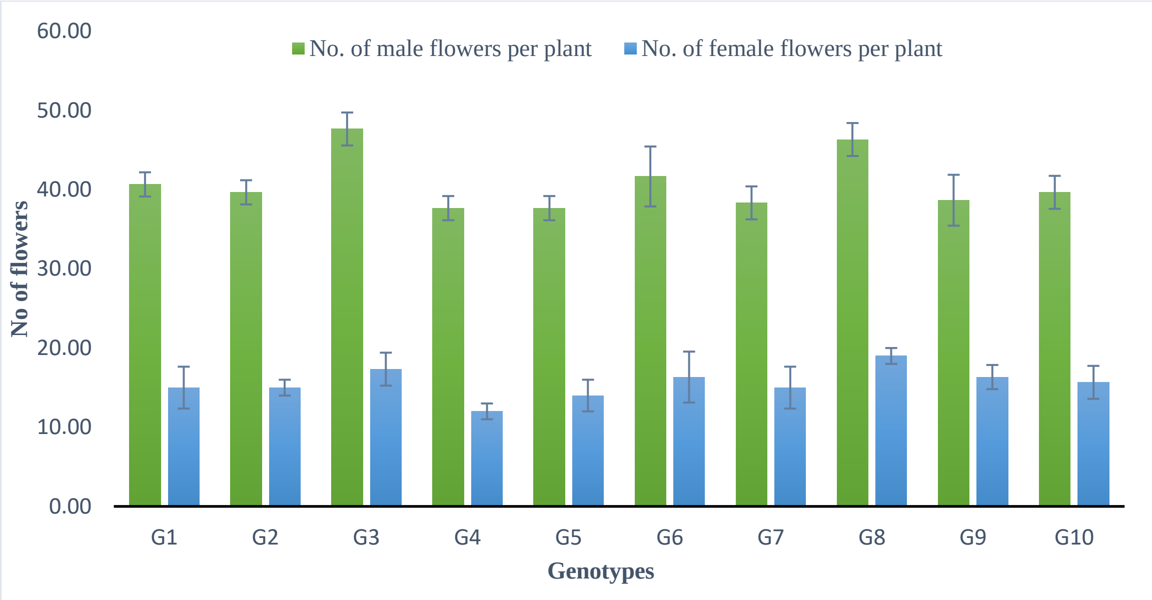

Figure 2. Mean performance of no. of male flowers per plant and no. of female flowers per plant in 10 genotype of bottle gourd

Plate 7. The pictorial view showing male and female flower

Plate 7. The pictorial view showing male and female flower

variance (42.16) was high then we can say there is a high environmental effect or the character has an effect on environment. The phenotypic co-efficient of variation was higher than the genotypic co-efficient of variation (Table 6). The medium value of genotypic co-efficient of variation (GCV) of the trait suggested the moderate possibility of yield improvement through selection of the trait. Rambabu *et al.* (2017) was observed similar results on this character. High heritability of (98.65%) with moderate genetic advance (13.29) was noted for the character and the value of genetic advance in percent of mean was high (36.79) (Table 6) indicated that fruit length may be controlled by additive genes and selection may be effective for this character. Dubey *et al.* (2022) found moderate heritability with different genetic advance but Lal *et.al.* (2021), Rabbi (2020) found the same result in case of fruit length.

4.2.11 Fruit diameter (cm)

The estimated data revealed that the maximum diameter was recorded in G5 (54.09 cm) followed by G8 (53.67 cm) and the minimum number was in G2 (27.87 cm) followed by G1 (31.30 cm) with mean value 40.12 (Table 5). The difference between phenotypic variance (91.53) and genotypic variance (90.96) was with large environmental influence. The phenotypic co-efficient of variation was higher than the genotypic co-efficient of variation (Table 6). The high values of genotypic co-efficient of variation (GCV) for this trait suggested the possibility of yield improvement through selection of the trait. So that the trait should be consider during parent selection for breeding program. Sultana *et al.* (2018) got same results of fruit diameter. High heritability of (99.38%) with moderate genetic advance (19.59) was noted for the character and the value of genetic advance in percent of mean was high (49.03) (Table 6). High heritability with high genetic advance in percent of mean indicated that this trait may be controlled by additive genes and selection may be effective for this character. Rashid *et al.* (2020b) showed high estimates of heritability coupled with high genetic advance (as percent of mean).

4.2.12 Fruit pedicel length (cm)

It was observed that the maximum number was recorded in G1 (12.57 cm) followed by in G2, G5 (12.10 cm) and the minimum number was in G3 (8.67 cm) followed by G9 (9.80) with mean value 10.76 (Table 5). The difference between phenotypic variance (1.75) and genotypic variance (1.54) was with slight environmental influence. The phenotypic co-efficient of variation was higher than the genotypic co-efficient of variation (Table 6) for this trait indicating that they all interacted with the environment to some extent. Rabbi (2020) and Karmakar (2015) also found same findings. High heritability of (88.23%) with low genetic advance (2.40) was noted for the character and the value of genetic advance in percent of mean was high (22.29) (Table 6) for fruit pedicel length, indicating this trait was mostly controlled additive genes. This suggested that the scope of improvement through selection may be effective. Lal *et al.* (2021) observed the same result.

4.2.13 Individual fruit weight (kg)

The estimated data revealed that the maximum fruit weight was in G5 (2.52 kg) followed by G4 (2.33 kg) and the minimum number was found in G2 (.95 kg) followed by G1 (1.02 kg) with mean value 1.72 (Table 5). Mean performance of individual fruit weight in 10 genotypes is presented in Figure 3. The difference between phenotypic variance (0.36) and genotypic variance (0.33) was with environmental influence. The phenotypic co-efficient of variation was higher than the genotypic co-efficient of variation (Table 6). The high value of genotypic co-efficient of variation (GCV) for the trait suggested the possibility of yield improvement through selection of the trait. So, this trait should be considered during parent selection for breeding program. Sultana *et al.* (2018) got same results with less environmental effect. High heritability coupled with high genetic advance in percent of mean was obtained in Individual fruit weight, indicating this trait was mostly controlled by additive genes. This suggested that the scope of improvement may be effective by the phenotypic selection based on this character. Vaidya *et al.* (2020) and Damor *et al.* (2016) also suggested that most likely heritability was due to additive gene effects and selection would be effective.

4.2.14 No. of seeds per fruit

It was observed that the maximum no. of seeds per fruit was recorded in G6 (441.73) followed by G4 (420.93). The lowest number was recorded in G8 (220.47) followed G5 (306.30) (Table 5). The difference between phenotypic variance (4916.63) and genotypic variance (4772.73) was with large environmental influence. The phenotypic co-efficient of variation was higher than the genotypic co-efficient of variation (Table 6). The medium value of genotypic co-efficient of variation (GCV) for

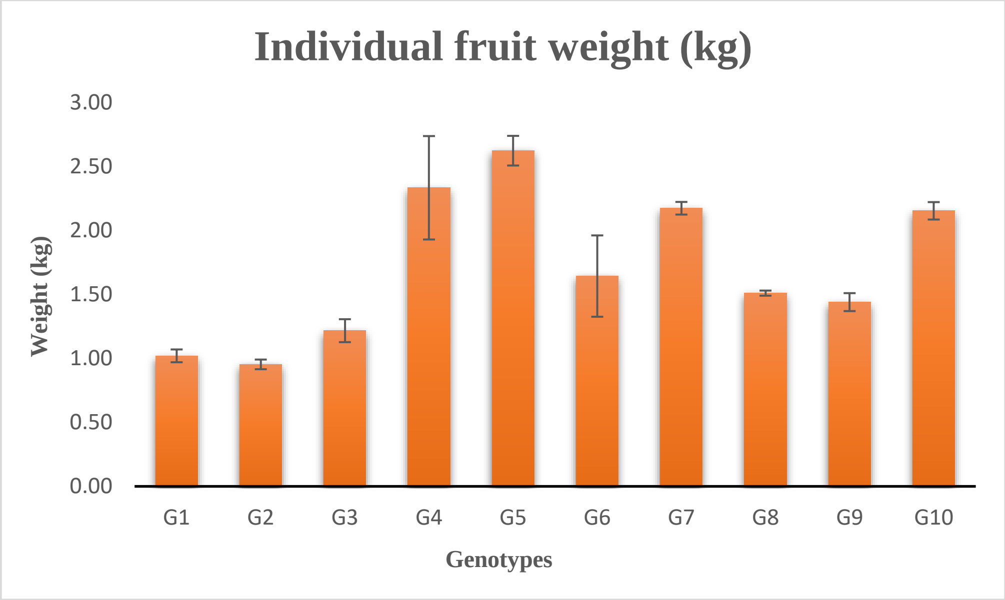

Figure 3. Mean performance of individual fruit weight in 10 genotypes of bottle gourd

the trait suggested the moderate possibility of yield improvement through selection of this trait. Rambabu *et al.* (2017) observed the similar result. High heritability (97.07%), high genetic advance (140.22) along with high genetic advance as per cent mean (38.04%) were noted. The character is governed by additive gene action and selection must be rewarding for such trait (Table 6). In this study, there is a wide scope for improvement through selection of this trait. The same result was by Rashid *et al.* (2020b), Kandasamy *et al.* (2019) in bottle gourd.

4.2.15 100 seed weight (g)

The estimated data revealed that the highest weight of 100 seed weight was recorded in G5 (20.50 gm) followed by G6 (20.16 gm) and the lowest were in G8(12.70 gm), G2 (14.57 gm), respectively with mean value 16.89 (Table 5). The phenotypic variance was (6.77) and the genotypic variance was (4.97). Phenotypic co-efficient of variations (PCV) were higher than the genotypic co-efficient of variation (GCV) for this trait (Table 6) indicating that they all interacted with the environment to some extent. Rabbi (2020), Sultana *et al.* (2018) and Rambabu *et al.* (2017) also found the similar result on 100 seed weight (g). High heritability (73.46%) with low genetic advance (3.94) was noted for the character and the value of genetic advance in percent of mean was high (23.23) (Table 6). High heritability coupled with high genetic advance in percent of mean was obtained for 100 seed weight was mostly controlled by additive genes. This suggested that the scope of improvement through selection may be effective based on the trait. Similar findings were previously reported by Deepthi *et al.* (2016), Kumar *et al.* (2007), Damor *et al.* (2016) and Rahman khan *et al.* (2016).

4.2.16 Seed length (cm)

The highest length was recorded was in G3 (1.90cm) followed by G5 (1.80) and the lowest seed length was recorded in G2 (1.30 cm) followed by G4 (1.41 cm) with mean value 1.59 (Table 5). The phenotypic co-efficient of variation was higher than the genotypic co-efficient of variation (Table 6). Rambabu *et al.* (2017) also found the similar result on seed length (cm). High heritability of (80.85%) with low genetic advance (0.34) was noted for the character and high genetic advance in percent of mean was recorded as 21.47 % (Table 6). High heritability coupled with high genetic advance in percent of mean was obtained for Seed length, indicating this trait was mostly controlled by additive genes. The scope of improvement by selection of the trait may be possible. These findings are supported with the findings of Tirumalesh *et al*. (2016) and Rajawat and Collis (2017).

4.2.17 Seed breadth (cm)

It was found that the maximum number was recorded in G5 (0.82 cm) followed by G10 (0.81 cm) and the minimum number was in G8 (0.52 cm) followed by G2 (0.63 cm) with mean value 0.70 (Table 5). The difference between phenotypic variance (0.01) and genotypic variance (0.01). The phenotypic co-efficient of variation was higher than the genotypic co-efficient of variation (Table 6). High heritability (86.25%) with low genetic advance (0.17) was noted for the character and the value of genetic advance in percent of mean was high (24.72) (Table 6). High heritability coupled with high genetic advance in percent of mean was obtained for seed breadth, indicating this trait was mostly controlled by additive genes. This suggested that the scope of improvement using selection may be effective. Husna *et al.* (2011), Jat *et al.* (2014) and Koppad *et al.* also reported the same findings.

4.2.18 Seed Thickness (cm)

The highest number was recorded in G5 (0.22 cm) followed by G2, G7 and G9 (0.21 cm) and the lowest number was in G8 (0.13 cm) followed by G3 (0.17 cm) with mean value 0.19 (Table 5). The phenotypic variance (0.0005) was higher than the genotypic variance (0.0004) and their difference is low due to the lowest environmental effect on that character. The phenotypic co-efficient of variation was higher than the genotypic co-efficient of variation (Table 6). Moderate heritability (47.90%), low genetic advance (0.03) along with moderate genetic advance as percent mean (16.60%) (Table 6) coupled this trait was mostly controlled by additive genes and non-additive genes. This indicates transmission of genes related to this trait to further generation may be possible. Similar results were found by Islam *et al.* (2009) in bitter gourd.

4.2.19 Fruit yield per plant (kg)

It was observed that the maximum number was recorded in G5 (26.31 kg) followed by G6 (20.67 kg) and the minimum number was in G2 (9.84 kg) followed by G1 (10.22 kg) with mean value 17.41 (Table 5). Mean performance of fruit yield per plant in 10 genotypes is presented in Figure 4. The difference between phenotypic variance (30.75) and genotypic variance (25.41). The difference between phenotypic and genotypic

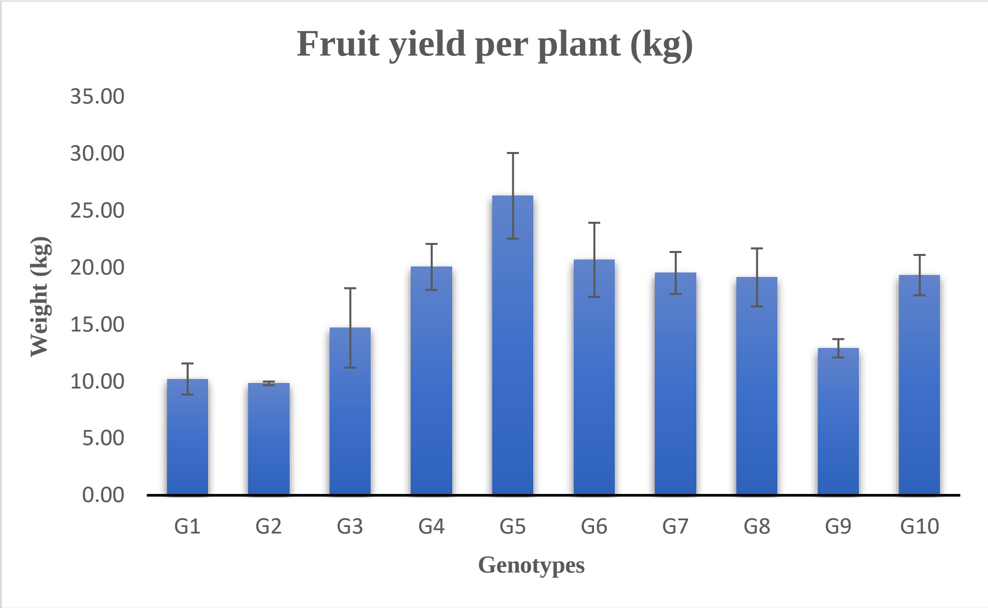

Figure 4. Mean performance of fruit yield per plant in 10 genotypes of bottle gourd

variance is high then we can say there is a high environmental effect or the character has an effect on environment. The phenotypic co-efficient of variation was higher than the genotypic co-efficient of variation (Table 6). Dubey *et al.* (2022), Rabbi (2020) and Sultana *et al.* (2018) found same results of this yield contributing character. High heritability coupled with high genetic advance in percent of mean was obtained for this trait indicating the preponderance of additive gene action which indicates the best possibility of improvement through selection procedure. The results were found with the conclusions of Deepthi *et al.* (2016), Rani and Reddy (2017) in bottle gourd.

4.3 Correlation Co-efficient

Correlation co-efficient is a numerical measure of some type of interrelation to detect the direction and strength of relationship between the relative movements of two or more variables. The values of correlation co-efficient range between -1.0 and 1.0. A correlation of -1.0 exhibits a perfect negative correlation, whereas a correlation of 1.0 exhibits a perfect positive correlation. Whereas a correlation of 0.0 exhibits no relationship between of the two variables. Yield is a complex trait being influenced by several interdependent quantitative characters. Selection for yield may not be effective unless the directly or indirectly influences of other yield components are taken into consideration. When selection pressure is exercised for improvement of any character highly associated with yield, it simultaneously affects a number of other correlated traits. Hence knowledge regarding association of character with yield and among themselves provides guidelines to the plant breeder for making improvement through selection. Higher genotypic correlations than phenotypic one might be due to modifying or masking effect of environment in the expression of the character under study (Nandpuri *et al.* 1973). Results of genotypic and phenotypic correlation co-efficient of yield and its contributing traits of bottle gourd were estimated separately as vegetative character and reproductive character with yield and shown in Table 7 which discussed character wise as follows:

4.3.1 Days to 1st male flowering

Days to 1st male flowering exhibited significant and positive correlation with days to 1st female flowering (r_g=0.833, r_p=0.981), leaf length (r_p=0.421) pointing out a possible increase in days to 1st female flowering and leaf length by increasing days to 1st male flowering. It showed insignificant and positive correlation with leaf length (r_g=0.231), leaf breadth (r_g=0.182, r_p=0.276), no. of male flowers per plant (r_p=0.035), no. of female flowers per plant (r_g=0.081, r_p=0.036), fruit diameter (r_g=0.135, r_p=0.162), no. of fruits per plant (r_g=0.064), no. of seeds per fruit (r_g=0.026, r_p=0.045), individual fruit weight (r_g=0.023, r_p=.054) and fruit yield per plant (r_g=0.064, r_p=0.025) indicating very little contribution of these traits toward the increase in leaf length, leaf breadth, no. of male flowers per plant, no. of female flowers per plant**,** fruit diameter, no. of fruits per plant, no. of seeds per fruit, individual fruit weight and fruit yield per plant. It also showed insignificant and negative correlation with no. of male flowers (r_g=-0.028), fruit length (r_g=-0.213, r_p=-0.228), no. of fruits per plant (r_p=-0.049) and 100 seed weight (r_g=-0.159, r_p=-0.279). Insignificant association of these traits revealed that the combination between these traits was largely influenced by environmental factors. Panigrahi *et al.* (2018) and Karmokar (2015) also found the similar result in their bottle gourd experiment.

4.3.2 Days to 1st female flowering

Days to 1st female flowering exhibited insignificant and positive correlation with leaf length (r_g=0.213, r_p=0.314), leaf breadth (r_g=0.106, r_p=0.131), and no. of seeds per fruit (r_g=0.193, r_p=0.217) indicating very little contribution of this trait towards the increase in leaf length, leaf breadth, no. of seeds per fruit. It also showed insignificant and negative correlation with no. of male flowers per plant (r_g= -0.087, r_p= -0.093), no. of female flowers per plant (r_g= -0.112, r_p= -0.105), fruit length (r_g=-0.081, r_p=-0.081), fruit diameter (r_g=-0.011, r_p=-0.008), 100 seed weight (r_g=-0.153, r_p=-0.127), individual fruit weight (r_g=-0.038, r_p=-0.038) and fruit yield per plant (r_g=-0.100, r_p=-0.077). Insignificant association of these traits revealed that the combination between these traits was largely influenced by environmental factors. Dubey *et al.* (2022) also found quite similar result which was insignificant but positively correlated.

4.3.3 Leaf length (cm)

Leaf length exhibited significant and positive correlation with no. of female flowers (r_p=0.624) and it’s pointing out a possible increase in no. of female flowers per plant by increasing leaf length. It showed insignificant and positive correlation with leaf breadth (r_g=0.285, r_p=0.239), no. of male flowers per plant (r_g=0.185, r_p=0.198), no. of female flowers per plant (r_g=0.246) and no. of fruits per plant (r_g=0.117, r_p=0.169)

Table 7. Co-efficient of genotypic and phenotypic correlation among different yield components

Traits		DFMF	DFFF	LL	LB	NMFP	NFFP	FL	FD	NFP	NSPF	HSW	IFW
DFFF	r_g	0.833**											
	r_p	0.981**											
LL	r_g	0.231	0.213										
	r_p	0.421*	0.314										
LB	r_g	0.182	0.106	0.285									
	r_p	0.276	0.131	0.239									
NMF	r_g	-0.028	-0.087	0.185	-0.297								
	r_p	0.035	-0.093	0.198	-0.442*								
NFF	r_g	0.081	-0.112	0.246	-0.282	0.633**							
	r_p	0.036	-0.105	0.624**	-0.362*	0.969**							
FL	r_g	-0.213	-0.081	-0.168	-0.145	-0.118	-0.219						
	r_p	-0.228	-0.081	-0.261	-0.177	-0.165	-0.313						
FD	r_g	0.135	-0.011	-0.128	0.404*	-0.125	-0.090	-0.681**					
	r_p	0.162	-0.008	-0.194	0.533**	-0.150	-0.116	-0.692**					
NFP	r_g	0.064	-0.093	0.117	-0.001	0.609**	0.599**	-0.175	-0.092				
	r_p	-0.049	-0.052	0.169	-0.147	0.977**	0.827**	-0.206	-0.112				
NSPF	r_g	0.026	0.193	-0.165	-0.041	-0.289	-0.303	0.875**	-0.427*	-0.331			
	r_p	0.045	0.217	-0.286	-0.027	-0.394*	-0.464**	0.888**	-0.434*	-0.369*			
HSW	r_g	-0.159	-0.153	-0.035	0.505**	-0.317	-0.328	0.404*	0.048	-0.142	0.469**		
	r_p	-0.279	-0.127	-0.062	0.824**	-0.484**	-0.712**	0.446*	0.061	-0.128	0.494**		
IFW	r_g	0.023	-0.038	-0.236	0.473**	-0.469**	-0.420*	-0.095	0.727**	-0.378*	0.183	0.513**	
	r_p	0.054	-0.038	-0.319	0.738**	-0.547**	-0.561**	-0.119	0.751**	-0.446*	0.178	0.578**	
FYPP	r_g	0.064	-0.100	-0.140	0.538**	-0.192	-0.115	-0.214	0.726**	0.149	-0.008	0.479**	0.855**
	r_p	0.025	-0.077	-0.237	0.795**	-0.181	-0.233	-0.251	0.789**	-0.040	0.006	0.604**	0.911**

indicating very little contribution of this trait towards the increase in leaf breadth, no. of male flowers per plant, no. of female flowers per plant, no. of fruits per plant. It also showed insignificant and negative correlation with fruit length (r_g=-0.168, r_p=-0.261), fruit diameter (r_g=-0.128, r_p=-0.194), no. of seeds per fruits (r_g=-0.165, r_p=-0.286), 100 seed weight (r_g=-0.035, r_p=-0.062), individual fruit weight (r_g=-0.236, r_p=-0.319), fruit yield per plant (r_g=-0.140, r_p=-0.237). Insignificant association of these traits revealed that the combination between these traits was largely influenced by environmental factors. Panigrahi *et al.* (2018) found the character leaf length showed positive significant correlation with leaf width (0.241, 0.522), nodes to 1st male flower opening (0.345, 0.465) and diameter of fruit (0.170, 0.274) at both genotypic and phenotypic level. Similar results were noticed by Singh *et al.* (1996) and Ahmed *et al.* (2005)

4.3.4 Leaf breadth (cm)

Leaf breadth exhibited significant and positive correlation with fruit diameter (r_g=0.404, r_p=0.533), 100 seed weight (r_g=0.505, r_p=0.824), individual fruit weight (r_g=0.473, r_p=0.738) and fruit yield per plant (r_g=0.538, r_p=0.795) pointing out a possible increase in fruit diameter, 100 seed weight, individual fruit weight, fruit yield per plant by increasing leaf breadth. Correlation of leaf breadth with no. of male flowers per plant (r_p= -0.442) and no. of female flowers per plant (r_p=-0.362) was significant and negative indicating a possible increase in no. of male flowers per plant and no. of female flowers per plant by decreasing leaf breadth. It also showed insignificant and negative correlation with no. of male flowers per plant (r_g=-0.297), no. of female flowers per plant (r_g=-0.282), fruit length (r_g=-0.145, r_p=-0.177), no. of fruits per plant (r_g=-0.001, r_p=-0.147) and no. of seeds per fruit (r_g=-0.041, r_p=-0.027). Insignificant association of these traits revealed that the combination between these traits was largely influenced by environmental factors. Panigrahi *et al.* (2018) found the character leaf width showed positive significant association with days to 50% germination (0.306, 0.233), nodes to 1st male flower opening (0.242, 0.351) and negatively correlated with nodes to 1st female flower opening (-0.206, -0.513) at phenotypic and genotypic level.

4.3.5 No. of male flowers per plant

No. of male flowers per plant exhibited significant and positive correlation with no. of female flowers per plant (r_g= 0.633, r_p= 0.969) and no. of fruit per plant (r_g= 0.609, r_p= 0.977) pointing out a possible increase in no. of female flowers and no. of fruit per plant by increasing no. of male flowers per plant. Correlation of no. of male flowers per plant with no. of seeds per fruits (r_p=-0.394), 100 seed weight (r_p=-0.484), individual fruit weight (r_g=-0.469, r_p=-0.547) was significant and negative indicating a possible increase in no. of seeds per fruits, 100 seed weight, individual fruit weight by decreasing no. of male flowers per plant. It also showed insignificant and negative correlation with fruit length (r_g=-0.118, r_p=-0.165), fruit diameter (r_g=-0.125, r_p=-0.150), no. of seeds per fruits (r_g=-0.289), 100 seed weight (r_g=-0.317) and fruit yield per plant (r_g=-0.192, r_p=-0.181). Insignificant association of these traits revealed that the combination between these traits was largely influenced by environmental factors.

4.3.6 No. of female flowers per plant

No. of female flowers per plant exhibited significant and positive correlation with no. of fruits per plant (r_g= 0.599, r_p= 0.827) pointing out a possible increase in no. of fruits per plant by increasing no. of female flowers per plant. Correlation of no. of female flowers with no. of seeds per fruits (r_p=-0.464), 100 seed weight (r_p=-0.712), individual fruit weight (r_g=-0.420, r_p=-0.561) was significant and negative and indicating a possible increase in no. of seeds per fruits, 100 seed weight, individual fruit weight by decreasing no. of female flowers per plant. It also showed insignificant and negative correlation with fruit length (r_g=-0.219, r_p=-0.313), fruit diameter (r_g=-0.090, r_p=-0.116), no. of seeds per fruits (r_g=-0.303), 100 seed weight (r_g=-0.328), and fruit yield per plant (r_g=-0.115, r_p=-0.233). Insignificant association of these traits revealed that the combination between these traits was largely influenced by environmental factors.

4.3.7 Fruit length (cm)

Fruit length showed a significant and positive correlation with no. of seeds per fruits (r_g=0.875, r_p=0.888) and 100 seed weight (r_g=0.404, r_p=446) pointing out a possible increase in no. of seeds per fruits and 100 seed weight by increasing fruit length.

Correlation of fruit length with fruit diameter (r_g=-0.681, r_p=-0.692) was significant and negative and indicating a possible increase in fruit diameter by decreasing fruit length. It also showed insignificant and negative correlation with no. of fruits per plant (r_g= -0.175, r_p= -0.206), individual fruit weight (r_g=-0.095, r_p=-0.119) and fruit yield per plant (r_g=-0.214, r_p=-0.251). It indicating that the combination between these traits were largely influenced by environmental factors. Rashid *et al.* (2020a), Rabbi (2020) revealed that fruit length (cm) showed significant and positive correlation. Husna (2011) also found similar result in bottle gourd.

4.3.8 Fruit diameter (cm)

Fruit diameter exhibited significant and positive correlation with individual fruit weight (r_g=0.727, r_p=0.751) and fruit yield per plant (r_g=0.726, r_p=0.789) pointing out a possible increase in individual fruit weight and fruit yield per plant by increasing fruit diameter. It showed insignificant and positive correlation with 100 seed weight (r_g=0.048, r_p=0.061) indicating very little contribution of this trait towards the increase in 100 seed weight per plant. Correlation of fruit diameter with no. of seeds per fruit (r_g= -0.427, r_p= -0.434) was significant and negative and indicating a possible increase in no. of seeds per fruit by decreasing fruit diameter. It also showed insignificant and negative correlation with no. of fruits per plant (r_g= -0.092, r_p= -0.112). Insignificant correlation revealed the combination between these traits was largely influenced by environmental factors. Karmokar (2015) expressed the quite same result.

4.3.9 No. of fruits per plant

No. of fruits per plant showed insignificant and positive correlation with fruit yield per plant (r_g=0.149) indicating very little contribution of this trait towards the increase in fruit yield per plant. Correlation of no. of fruits per plant with no. of seeds per fruit (r_p= -0.369) and individual fruit weight (rg=-0.378, r_p=-0.446) was significant and negative and indicating a possible increase in no. of seeds per fruit and individual fruit weight by decreasing no. of fruits per plant. It also showed insignificant and negative correlation with no. of seeds per fruit (r_g= -0.369), 100 seed weight (r_g=-0.142, r_p=-0.128) and fruit yield per plant (r_p=-0.040). It indicating that the combination between these traits were largely influenced by environmental factors. Kunjam *et al.* (2019) and Karmokar (2015) got the same outcome from their research.

4.3.10 No. of seeds per fruits

No. of seeds per fruits exhibited significant and positive correlation with 100 seed weight (r_g= 0.469, r_p=0.494) pointing out a possible increase in 100 seed weight by increasing no. of seeds per fruits. It showed insignificant and positive correlation with individual fruit weight (r_g=0.183, r_p=0.178) and fruit yield per plant (r_p=0.006) indicating very little contribution of this trait towards the increase in individual fruit weight and fruit yield per plant. It also showed insignificant and negative correlation with fruit yield per plant (r_g=-0.008) and indicating that the combination between this trait was largely influenced by environmental factors. Rabbi (2020) got that no. of seeds per fruit showed non-significant but positive correlation.

4.3.11 100 seed weight (g)

100 seed weight was found highly significant and positively correlated with individual fruit weight (r_g=0.513, r_p=0.578) and fruit yield per plant (r_g = 0.479 r_p=0.604) indicating that a possible increase in individual fruit weight and fruit yield per plant by increasing 100 seed weight.

4.3.12 Individual fruit weight (kg)

Individual Fruit Weight exhibited significant and positive correlation with fruit yield per plant (r_g = 0.855 r_p=0.911) indicating that a possible increase in fruit yield per plant by increasing individual fruit weight. Rehan *et al.* (2020) got the same outcome from their research.

4.4 Path co-efficient analysis:

Complex relationships between the various traits related to the dependent variable can't be figured out through simple correlation. Correlation co-efficient exhibit linear association between variables. But it is not enough to describe these relationships when the causal relationship among variables is necessary. Therefore, it was suggested that path co-efficient analysis is the most common statistical method utilized to determine the direct or indirect effects of yield contributing characters on fruit yield per plant and measure the relative importance of each component on fruit yield per plant. Fruit yield per plant is considered as dependent (resultant) variable and its attributes as independent variables (causal) such as days to 1st male flowering, days to 1st female flowering, leaf length (cm), leaf breadth (cm), no. of male flowers per plant, no. of female flowers per plant, fruit length (cm), fruit diameter (cm), no. of fruits per plant, individual fruit weight (kg), no. of seeds per fruits, 100 seed weight (gm). Partitioning of genotypic correlations into direct and indirect effects of important characters by path co-efficient analysis of bottle gourd is presented in (Table 8). Residual effects of their independent variables have been denoted as 'R' which have influenced on fruit yield per plant to a low extent.

4.4.1 Days to 1st male flowering

Path co-efficient analysis revealed that days to 1st male flowering had negative direct effect (-0.137) on fruit yield per plant (Table 8). The trait exhibited positive indirect effect on days to 1st female flowering (0.184), leaf length (0.108), no. of male flowers per plant (0.008), fruit diameter (0.010) and individual fruit weight (0.072) followed by negative indirect effect via leaf breadth (-0.095), no. of female flowers per plant (-0.006), fruit length (-0.028), no. of fruits per plant (-0.017), no. of seeds per fruits (-0.011), 100 seed weight (-0.060). Finally, the trait showed positive genotypic correlation with fruit yield per plant (0.064) which was non-significant. Kunjam *et al.* (2019) and Karmokar (2015) also found similar result in bottle gourd.

4.4.2 Days to 1st female flowering

The character showed a positive direct effect (0.187) on fruit yield per plant (Table 8). Days to 1st female flowering showed positive indirect effect on leaf length (0.081), no. of female flowers (0.018). The negative indirect character via days to 1st male flowering (-0.135), leaf breadth (-0.045), fruit length (- 0.010), no. of male flowers per plant (-0.021), no. of fruits per plant (-0.018), no. of seeds per fruit (-0.055), individual fruit weight (-0.051), 100 seed weight (-0.027) and fruit diameter showed no effect. Which finally produced a negative non-significant genotypic correlation with fruit yield per plant (-0.100) (Table 5). Karmokar (2015) also found similar result.

4.4.3 Leaf length (cm)

Leaf length showed positive direct effect (0.257) on yield. The character showed positive indirect effect via days to 1st female flowering (0.059) followed by no. of male flowers per plant (0.045), no. of fruits per plant (0.059), no. of seeds per fruits (0.073). The negative indirect character via days to 1st male flowering (-0.058), leaf breadth (-0.082), no. of female flowers per plant (-0.105), fruit length (-0.032), fruit diameter (-0.012), 100 seed weight (-0.013) and individual fruit weight (-0.426) through which finally produced a negative insignificant genotypic correlation with fruit yield per plant (-0.140) (Table 8).

Table 8. Partitioning of genotypic into direct and indirect effects of morphological characters of 10 bottle gourd genotypes by path coefficient analysis

Traits	DFMF	DFFF	LL	LB	NMFP	NFFP	FL	FD	NFP	NSPF	HSW	IFW	Genotypic correlation with FYPP
DFMF	**-0.137**	0.184	0.108	-0.095	0.008	-0.006	-0.028	0.010	-0.017	-0.011	-0.060	0.072	0.064^{NS}
DFFF	-0.135	**0.187**	0.081	-0.045	-0.021	0.018	-0.010	0.000	-0.018	-0.055	-0.027	-0.051	-0.100^{NS}
LL	-0.058	0.059	**0.257**	-0.082	0.045	-0.105	-0.032	-0.012	0.059	0.073	-0.013	-0.426	-0.140^{NS}
LB	-0.038	0.024	0.061	**-0.345**	-0.100	0.061	-0.022	0.032	-0.051	0.007	0.178	0.987	0.538**
NMF	-0.005	-0.017	0.051	0.153	**0.226**	-0.164	-0.021	-0.009	0.341	0.100	-0.105	-0.732	-0.192^{NS}
NFF	-0.005	-0.020	0.160	0.125	0.219	**-0.169**	-0.039	-0.007	0.289	0.118	-0.154	-0.750	-0.115^{NS}
FL	0.031	-0.015	-0.067	0.061	-0.037	0.053	**0.124**	-0.041	-0.072	-0.225	0.097	-0.159	-0.214^{NS}
FD	-0.022	-0.001	-0.050	-0.184	-0.034	0.020	-0.086	**0.059**	-0.039	0.110	0.013	1.004	0.726**
NFP	0.007	-0.010	0.044	0.051	0.220	-0.140	-0.026	-0.007	**0.349**	0.094	-0.028	-0.596	0.149^{NS}
NSPF	-0.006	0.041	-0.074	0.009	-0.089	0.078	0.110	-0.026	-0.129	**-0.254**	0.107	0.237	-0.008^{NS}
HSW	0.038	-0.024	-0.016	-0.284	-0.109	0.120	0.055	0.004	-0.045	-0.125	**0.216**	0.773	0.479**
IFW	-0.007	-0.007	-0.082	-0.255	-0.123	0.095	-0.015	0.044	-0.156	-0.045	0.125	**1.337**	0.855**
Residual effect 0.005													

* Indicates significant at 0.05 probability level, ** indicates significant at 0.01 probability level

LL=Leaf length (cm), LB=Leaf breadth (cm), LPL=Leaf petiole length (cm), ID=Internodes distance (cm), DFMF=Days of 1st male flowering, DFFF=Days of 1st female flowering, NMFP =No. of male flowers per plant, NFFP=No. of female flowers per plant, NFP=No. of fruits per plant, FL=Fruit length (cm), FD=Fruit diameter (cm), LP=Length of petiole (cm), IFW=Individual fruit weight (kg), NSPF =No. of seeds per fruit, HSW=100 seed weight (g), SL=Seed length (cm), SB=Seed breadth (cm), ST=Seed thickness (cm) and FYPP=Fruit yield per plant (kg)

4.4.4 Leaf breadth (cm)

The character showed a negative direct effect (-0.345) on yield (Table 8). The character showed positive indirect effect on days to 1st female flowering (0.024), leaf length (0.061), no. of female flowers per plant (0.061), fruit diameter (0.032), no. of seeds per fruits (0.007), 100 seed weight (0.178), individual fruit weight (0.987). The negative indirect character via days to 1st male flowering (-0.038), no. of male flowers per plant (-0.100), fruit length (-0.022), no. of fruits per plant (-0.051) which finally produced a highly positive significant genotypic correlation with fruit yield per plant (0.538) (Table 5) (Table 8).

4.4.5 No. of male flowers per plant

No. of male flowers per plant showed positive direct effect (0.226) on fruit yield (Table 8). The character showed positive indirect effect via leaf length (0.051), leaf breadth (0.153), no. of fruits per plant (0.341), no. of seeds per fruits (0.100). The negative indirect character via days to 1st male flowering (-0.005), days to 1st female flowering (-0.017), no. of female flowers per plant (-0.164), fruit length (-0.021), fruit diameter (-0.009), 100 seed weight (-0.105), individual fruit weight (-0.732) through which finally produced a negative insignificant genotypic correlation with fruit yield per plant (-0.192) (Table 8).

4.4.6 No. of female flowers per plant

No. of female flowers per plant showed negative direct effect (-0.169) on yield per plant. The character showed positive indirect effect via leaf length (0.160), leaf breadth (0.125), no. of male flowers per plant (0.219), no. of fruits per plant (0.289), no. of seeds per fruits (0.118). The negative indirect character via days to 1st male flowering (-0.005), days to 1st female flowering (-0.020), fruit length (-0.039), fruit diameter (-0.007), 100 seed weight (-0.154), individual fruit weight (-0.750). Finally, the trait showed negative genotypic correlation with fruit yield per plant (-0.115) which was non-significant. (Table 8)

4.4.7 Fruit length (cm)

Fruit length showed positive direct effect (0.124) on yield (Table 8). It showed positive indirect effect via days to 1st male flowering (0.031), leaf breadth (0.061), no. of female flowers per plant (0.053) and 100 seed weight (0.097). The character also produced negative indirect effect on yield through days to 1st female flowering (-0.015), leaf length (-0.067), no. of male flowers per plant (-0.037), fruit diameter (-0.041), no. of fruits per plant (-0.072), no. of seeds per fruits (-0.225), individual fruit weight (-0.159). The cumulative effect produced a highly non-significant negative genotypic correlation with yield (-0.214) (Table 8). Rabbi (2020) and Karmakar (2015) revealed that fruit length (cm) showed positive direct effect.

4.4.8 Fruit diameter (cm)

Fruit diameter showed positive direct effect (0.059) on yield (Table 8). It showed positive indirect effect via no. of female flowers per plant (0.020) followed by no. of seeds per fruits (0.110), 100 seed weight (0.013), individual fruit weight (1.004). The character also produced negative indirect effect on yield through days to 1st male flowering (-0.022), days to 1st female flowering (-0.001), leaf length (-0.050), leaf breadth (-0.184), no. of male flowers per plant (-0.034), fruit length (-0.086), no. of fruits per plant (-0.039) and this effect produced a highly significant positive genotypic correlation with yield (0.726). (Table 8). Rashid *et al.* (2020a), Rabbi (2020) and Karmakar (2015) found similar result.

4.4.9 No. of fruits per plant

The character showed a positive direct effect (0.349) on yield (Table 8). The character showed positive indirect effect on days to 1st male flowering (0.007), leaf length (0.044), leaf breadth (0.051), no. of male flowers per plant (0.220), no. of seeds per fruits (0.094). The negative indirect character via days to 1st female flowering (-0.010), no. of female flowers per plant (-0.140), fruit length (-0.026), fruit diameter (-0.007), 100 seed weight (-0.028), individual fruit weight (-0.596) which finally exposed a highly positive non-significant genotypic correlation with fruit yield per plant (0.149) (Table 8).

4.4.10 No. of seeds per fruits

No. of seeds per fruit, the character showed a negative direct effect (-0.254) on yield per plant (Table 8). It showed positive indirect effect on days to 1st female flowering (0.041), leaf breadth (0.009), no. of female flowers per plant (0.078), fruit length (0.110), 100 seed weight (0.107), individual fruit weight (0.237). The negative indirect character via days to 1st male flowering (-0.006), leaf length (-0.074), no. of male flowers per plant (-0.089), fruit diameter (-0.026), no. of fruits per plant (-0.129), which actually demonstrated negative non-significant genotypic correlation with fruit yield per plant (-0.008) (Table 8). Rabbi (2020) revealed that number of seeds per fruit had a negative direct effect on fruit yield per plant.

4.4.11 100 seed weight (g)

It exhibited a positive direct effect (0.216) on yield per plant. It showed positive indirect effect on days to 1st male flowering (0.038), followed by no. of female flowers per plant (0.120), fruit length (0.055), fruit diameter (0.004), individual fruit weight (0.773). The character also produced negative indirect effect on days to 1st female flowering (-0.024) followed by leaf length (-0.016), leaf breadth (-0.284), no. of male flowers per plant (-0.109), no. of fruits per plant (-0.045), no. of seeds per fruits (-0.125) which caused a highly significant and positive genotypic correlation with fruit yield per plant (0.479) (Table 8).

4.4.12 Individual fruit weight (kg)

Individual Fruit Weight showed positive direct effect (1.337) on yield (Table 8). It also showed positive indirect effect on no. of female flowers (0.095), fruit diameter (0.044), 100 seed weight (0.125). The character also produced negative indirect effect on days to 1st male flowering (-0.007), days to 1st female flowering (-0.007), leaf length (-0.082), leaf breadth (-0.255), no. of male flowers per plant (-0.123), fruit length (-0.015), no. of fruits per plant (-0.156), no. of seeds per fruits (-0.045), and demonstrated positive with highly significant genotypic correlation with fruit yield per plant (0.855) (Table 8).

4.4.13 Residual effect

The residual effect (R) of path co-efficient analysis was 0.005 which reported that the traits under study contributed 99.50% to the fruit yield per plant. It is said that there were some other factors those contributed 0.5% to the fruit yield per plant that are not included in the present study could have significant effect on fruit yield per plant (Table 8).

CHAPTER V
SUMMARY AND CONCLUSION

The experiment was carried out using 10 genotypes of bottle gourd at the farm of Sher-e-Bangla Agricultural University, Dhaka to determine the genetic variability and selecting the superior genotypes for yield and its contributing traits during October 2020 to March 2021.

The field experiment was laid out in the main field in Randomized Complete Block Design (RCBD) with three replications. It was observed that significant variation exists among all the genotypes used for most of the characters studied. According to the mean performance the maximum leaf length (cm) was observed 20.49 cm in G1 and minimum was 17.97 cm recorded in G4. The maximum leaf breadth (cm) was observed 28.83 cm in G5 and minimum was 23.87 cm which was recorded in G8 and G10. Maximum leaf petiole length (cm) was observed 15 cm in G5 and minimum was 10.17 cm which was found in G2. The maximum internodes distance was observed 18.10 cm in G5 and minimum was 13.63 cm which was recorded in G1. The maximum duration of days to 1st male flowering was observed 60 days in G7 and the minimum duration was 43.67 days in G10. The maximum duration of days to 1st female flowering was observed 61.33 days in G7 and the minimum duration was 43.67 days in G10. The maximum no. of male flowers per plant was observed 47.67 flowers in G3 followed and the minimum no. was 37.67 flowers per plant in G4 and G5. The maximum no. of female flowers per plant was observed 19 flowers in G8 followed and the minimum no. was 12 flowers per plant in G4 followed. The maximum no. of fruits per plant was recorded 12.67 fruits in G6, G8 and the minimum no. was 8.67 fruits in G4. The maximum fruit length was recorded 42.30 cm in G6 and the minimum no. was 21.77 cm in G8. Maximum fruit diameter was recorded 54.09 cm in G5 and the minimum no. was 27.87 cm in G2. The maximum length of petiole was found 12.57 cm in G1 and the minimum number was 8.67 cm in G3. The maximum fruit weight was 2.62 kg in G5 and the minimum no. was found .95 kg in G2. The maximum no. of seeds per fruit was recorded 441.73 in G6 and lowest no. was recorded 220.47 in G8. The highest weight of 100 seed weight was recorded 20.50 gm in G5 and the lowest were 12.70 gm and 14.57 gm in G8. The highest seed length was recorded was 1.90 cm in G3 and the lowest seed length was recorded 1.30 cm in G2. The maximum seed breadth was recorded 0.82 cm in G5 and the minimum no. was 0.52 cm in G8. The highest seed thickness was recorded 0.22 cm in G5 and the lowest no. was 0.13 cm in G8. The maximum no. of fruit yield per plant was recorded 26.31 kg in G5 and the minimum no. was 9.84 kg in G2.

The phenotypic variance was higher than the corresponding genotypic variance for all the characters under studied indicating influence of environmental effects also associated with the expression of these characters. Characters like, fruit length (cm), fruit diameter (cm), no. of seeds per fruit, fruit yield per plant (kg) exhibited high genotypic and phenotypic co-efficient of variation. The phenotypic co-efficient of variation was higher than the genotypic co-efficient of variation for all the characters. Highest phenotypic co-efficient of variation (35.06) and genotypic co-efficient of variation (33.56) was found in individual fruit weight (kg).

However, high heritability coupled with high genetic advance as percentage of mean was found in no. of fruits per plant, fruit length, fruit diameter, fruit pedicel length, individual fruit weight, number of seeds per fruit, 100 seed weight, seed length, seed breadth and fruit yield per plant, hence inheritance of these traits was controlled by the additive gene actions whereas rest of the traits was governed by non-additive gene actions.

Investigation on character association indicating that fruit yield per plant had highest significant positive correlation with leaf breadth (cm), fruit diameter (cm), 100 seed weight (g) and individual fruit weight (kg) in both genotypic and phenotypic level indicating the importance of these trait in selection for increasing yield and were identified as yield attributing characters. Thus, selection can be relied upon these characters for the genetic improvement of yield of bottle gourd. Path analysis revealed that highest positive direct effect was individual fruit weight (kg) (1.337) and the lowest positive direct effect was fruit diameter (cm) (0.059). Days to 1st female flowering, leaf length, no. of male flowers per plant, fruit length (cm), fruit diameter (cm), no. of fruits per plant, 100 seed weight (g) and individual fruit weight (g) showed positive direct effect on fruit yield per plant (kg) indicating that direct selection based on these traits may be helpful in evolving high yielding varieties of bottle gourd.

Selection was conducted among genotypes based on their yield and yield contributing characters. Among the selected traits, individual fruit weight and fruit diameter had a positive association with production. Moreover, no. of fruits per plant and 100 seed weight had a direct effect on generating the highest yield per plant genotypes. Therefore, considering the above relationship among the traits, genotypes G4, G5, G7. G8 and G10 can be recommended for future breeding programme.

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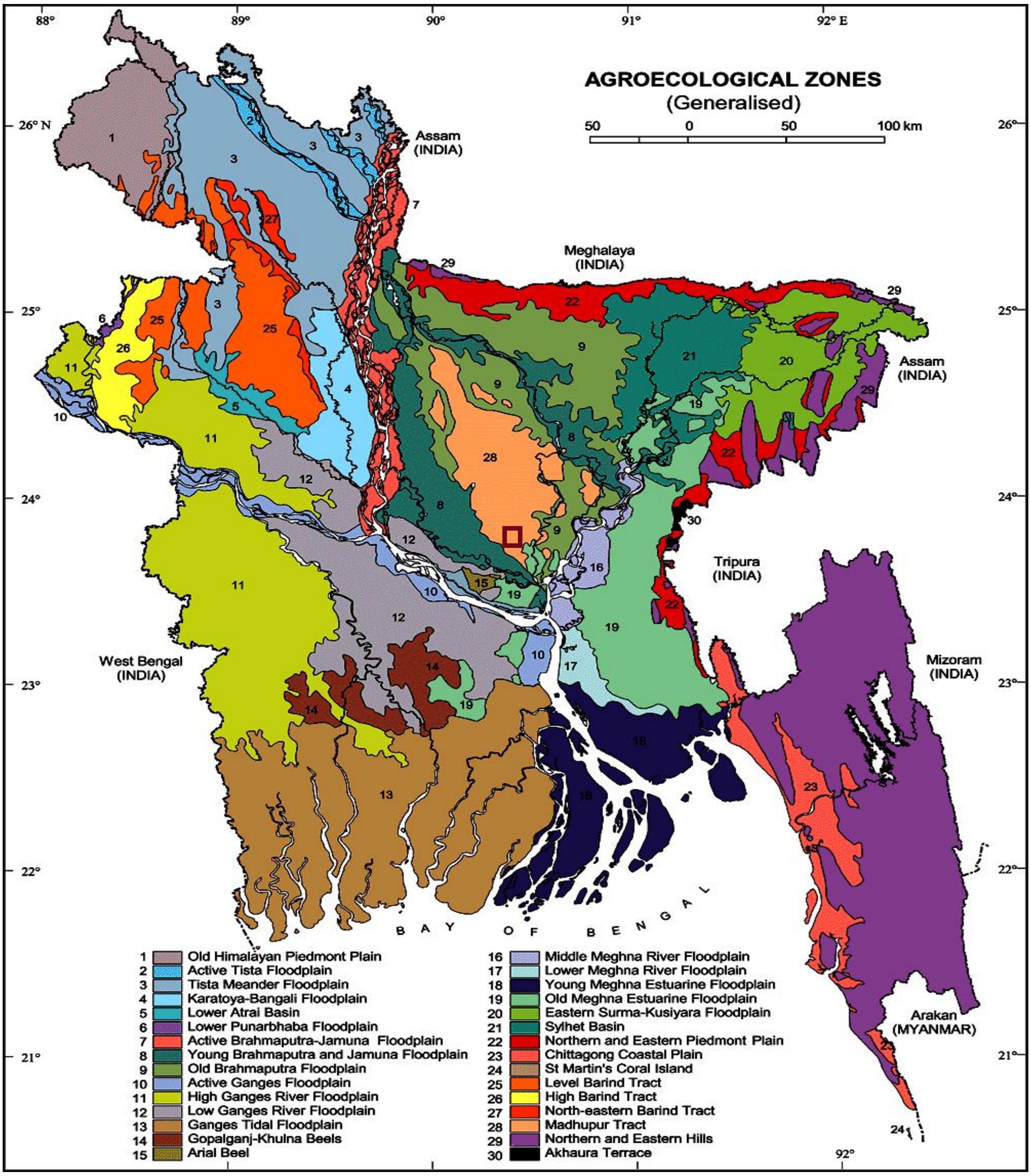
APPENDICES

Appendix I. Map showing the experimental site under the study



Appendix II: Physical and chemical characteristics of initial soil depth of the experimental site.

A. Physical composition of the soil:

Soil separates	Percentage (%)	Methods
Sand	36.90	Hydrometer method (Day, 1915)
Silt	26.40	Do
Clay	36.66	Do
Textural class	Clay loam	Do

B. Chemical composition of the soil:

SL NO.	Soil characteristics	Analytical data	Methods
1	Organic carbon (%)	0.82	Walkley and Black, 1947
2	Total N (kg/ha)	1790.00	Bremner and Mulvaney, 1965
3	Total P (ppm)	840.00	Olsen and Sommers, 1982
4	Total S (ppm)	225.00	Bardsley and Lanester, 1965
5	Available P (kg/ha)	69.00	Olsen and Dean, 1965
6	Available N (kg/ha)	54.00	Bremner, 1965
7	Available S (ppm)	16.00	Hunter, 1984
8	Exchangeable K (kg/ha)	89.50	Pratt, 1965
9	CEC	11.23	Chapman, 1965
10	pH (1:2.5 soil to water)	5.55	Jackson, 1958

Appendix III: Monthly average temperature, average relative humidity and total rainfall and total sunshine of the experimental site during the period from October, 2020 to March, 2021.

Month	Air temperature (^0C)		Relative humidity (%)	Total rainfall (mm)	Sunshine (hr)
	Minimum	Maximum			
October, 2020	24	32	72	172.3	7.4
November, 2020	19	30	66	34.4	7.9
December, 2020	15	27	63	12.8	7.9
January, 2021	13	25	54	7.7	7.9
February, 2021	16	28	49	28.9	8
March, 2021	21	32	45	65.8	8.3