*Original Research Article*

# Source-sink potential of maize inbreds grown in rainfed conditionin Bangladesh


**Abstract**

The experiment was conducted at the Plant Breeding Research Field, Department of Genetics and Plant Breeding, Hajee Mohammad Danesh Science and Technology University, Dinajpur, Bangladesh during the period of November, 2018 to March, 2019. The experiment was conducted at randomized complete block designwith three replications comprisedfifteen inbred lines. The individual plot size and spacing were 2m x 3m and 40cm x 60 cm respectively. Plant height (cm), cob length (cm), cob weight (g), cob diameter (cm), kernels/cob, 100-kernel weight (g) and yield/plant (g) were recorded from randomly selected ten plants/plot. To assess source (leaves) and sink (kernels), leaves/plant were counted at four growth stages of crop, 30 DAP, 45DAP, 60DAP and 75DAP (days after planting). Moreover, root lengths were measured four times at same interval and leaf length was measured at 75DAP only. Four inbred lines, IL 15, IL 32, IL 33 and IL 35 appeared high yield potential as compared to other lines and the highest yield (477.02 g/plant) was obtained from IL35. Three lines, IL32, IL33 and IL35 produced high root length and leaves/plant so, these lines apparently found outstanding for synthesizing more starch and providing mechanical support against lodging. Two characters, cob diameter and 100-kernel weight had high heritability. Plant height showed negative correlation with yield/plant, hence short stature plant is suitable for maize cultivation. The character, cod diameter alone exerted maximum direct effect (0.86273), followed by cob length (0.82606) and kernels/cob (0.77719). The negative direct effect of plant height (-0.7021) was not counter balanced and compensated by other indirect effects. The inbred lines, IL32, IL33 and IL35were promising for future breeding.The accumulation of starch in kernels was not uniform in rainfed condition which resulted average low kernel yield potential in maize inbred lines and may be improved through providing good agronomic requirements.


Keywords: Leaves counting, root growth, yield potential and parent selection.

## 1. INTRODUCTION

Maize (*Zea mays* L.) is a monophyletic originated large grain cereal grown around the world but it's major production areas are located in temperate regions [1]. Its native land is Mexico, derived from the wild species Teosinte (*Zeamaxicana*) possesses 2n=24 chromosomes.The Mexican Valley of Tehuacan, is considered the center of origin where it was found about 2750 years ago of BC. It is a source of both food and feed, and present conversion biofuel from this starch rich crop creates a threat on food and feed security around the world. If maize is used as supplementary food in our daily diets, protein uptake would significantly increase [2]. As a hole, this crop has global impact, especially staple food for 1 billion people of sub-Saharan and different countries of Latin America [3].It is also an important cereal in Asia but mainly used as feed for livestock; rapid economic growth along with urbanization compel the farmers of Indian sub-continent to incline maize cultivation predominantly for fodder and feed [4]. Bangladesh is the moderate producer of maize with a production of 28,45,691 metric tons [5] and about 32,88,102 metric tons in almost 9,89,582 acres' area [6]. This country is ideal for successful maize production because it can be grown everywhere throughout the year [7]. Being a short day crop, it sheds pollen well and matures quickly at a temperature ranged from $20^0$C to $30^0$C,prevailing in our country.In the year 2018-2019, The United States was the largest producer of maize with a production of 366.3million metric tons [8]and China and Brazil rounded off the top maize producing countries.It is one of the most important cereal crops in the world after wheat and rice [9] because of its multifarious use and high quantity grain yield per unit area [10] is contributing billions of dollars to the global economy [11]. The hybrid maize varieties currently cultivating throughout the country, are imported from India, China and Thailand. Development of outstanding parental lines rather than import of hybrid seeds may offer a sustainable maize production technology through cultivation of locally produced hybrid maize varieties [12].

Rapid change in climate, there is a need to produce high yielding hybrid maize varieties exploiting the locally developed inbred lines. The performance of inbred lines tested in rainfed condition is helpful in identification of superior inbred lines that may be exploited for the production of high yielding hybrid maize through appropriate incorporation in hybridization. [13]There is a strong relation between dry-matter production and grain yield in maize, minimum dry-matter production after harvest suggests low source at vegetative phase that eventually resulted low quantity grain yield due to limitation of sink capacity [14]. In addition, rapid maturation followed by bending down of leaves, indicate minimal photosynthetic product, sugar, is the principal source for the sink (kernels) [15], the physiological state of kernels ultimately suffers from possible utilization of sugar [16], which leads to develop infertile kernels in the cobs.

The efficiency of selection depends upon heritability and the genetic advance of individual character [17] and heritability estimates are useful for breeding of quantitative characters because it permits to determine the most effective selection strategy, breeding method used in a breeding program is to predict gain from selection [18]. Information regarding interrelationship between quantitatively inherited characters and their direct and indirect effects on grain yield are of great importance for success in selections to be conducted in breeding programs [19]. In path coefficient analysis, grain yield is considered as dependent variable and the remaining characters are considered as independent variables [20]. Moreover, grain yield is a complex character which is influenced by several component characters and direct selection for grain yield is often not be effective, therefore phenotypic association [21] and cause effects of the components are to be assessed through appropriate biometrical tools [22]. Therefore, before going to test combining ability of the developed parental lines, heritability of yield enhancing characters and association of these characters were investigated in this study.

## 2. MATERIALS AND METHODS

### 2.1 Experimental design and field operation

The field experiment was carried out at the Plant Breeding Research Farm, Department of Genetics and Plant Breeding, Hajee Mohammad Danesh Science and Technology University, Dinajpur, Bangladesh during the period from November, 2018 to March2019. Fifteen inbred lines were received from the departmental store and these lines were developed through successive selfing/inbreeding upto 7$^{th}$ generation. The experiment was conducted following randomized complete block design with three replications. The unit plot size and spacing were 3m x 5m and 20cm x 60cm respectively.The inbred lines were developed from exotic hybrid maize varieties through continuous selfing/inbreeding under the maize improvement program carried out by the Department of Genetics and Plant Breeding, Hajee Mohammad Danesh Science and Technology University, Dinajpur, Bangladesh. All agronomic requirements fulfilled, except no supplementary irrigation as the strategy of the experiment was rainfed condition. Rouging was followed began from germination and continued prior to harvesting in the field. Just after attaining 5% flowering the individual plants were selfed or inbred to maintain homozygosity in the individual parental lines. The cobs were protected from bird attack through netting just after completion of artificial selfing/inbreeding. Data were recorded on plant height (cm), root length (cm) and leaves/plant at 30,45,60 and 75 DAP (days after planting) and leaf length (cm) at 75DAP, cob length (cm), cod diameter (cm), cob weight (g), kernels/cob, 100-kernel weight (g) and yield/plant (g).

### 2.2 Statistical analysis of the recorded data

Mean data were statistically analyzed for each character separately. The analysis of variance for each of the character under study was performed by F test using GENSTAT 5.7.1 [23]. The significance differences for the studied characters among the inbreeds were performed by the Duncan's Multiple Range Test (DMRT) test at 5% level of probability [24]. Genetic parameters were estimated following the method proposed by [25] and correlation coefficient and path coefficient were estimated according to [26].Genetic advance was calculated following formula given by [25]and [27] and as percent of mean by the formula of [28].

## 3. RESULTS AND DISCUSSION

### 3.1 Crop husbandry and evaluation on inbred lines

In the present study yield/plant along with eight yield related characters, plant height (cm) leaves/plant, leaf length (cm), cob length (cm), cob diameter (cm), cob weight (g), kernels/cob, 100-kernel weight (g) and root length (cm) were measured to assess the contributions of the characters on yield in maize inbred lines. The results obtained from the study along with discussion of the results are described below-

The means of yield and yield related charactersare presented in Table 1. The means of a particular character against fifteen inbred lines are separated by DMRT. The mean plant height was 218. 66cm and lowest plant height was recorded from 4 inbred lines, IL15, IL32, IL33 and IL35. During crop husbandry, earthing up is indispensable to protect the inbred lines from lodging and such intercultural operation is laborious and costly, therefore, short stature inbred lines are suitable in maize breeding program. Number of leaves/plant were obtained at four different intervals started from 30DAP to 75DAP, hence the interval was 15days. It is observed from Table 2 that leaves/plant gradually increased with corresponding increase of DAP. The range of leaves/plant was 7.33 to 20.09 among the inbred lines. Since maize is a C4 plant, it utilizes a 4-carbon sugar during the Calvin cycle and uptakes more $CO_2$ to synthesize the source (starch) through photosynthesis for the sink (kernels). The process of transferring assimilated source in the green tissues into the developing kernels complicates the source versus sink question, as it is also affected by the environment, time, and the genetic makeup of the plants [29].Among the fifteen inbred lines, IL32, IL33 and IL35 apparently produced remarkable leaves/plant while counted at 4 stages, suggest these lines are desirable to produce more source for the kernels (sink). The mean cob length was estimated to 17.47 cm and highest length was obtained from the line IL15 (21.83 cm), which was statistically similar with the results obtained in IL 33 and IL 35.Similar finding was reported by [30]. The highest mean cob diameter was obtained from the line IL 33 (4.81 cm), which was statistically similar with the results obtained in IL 35. The cob diameter had effect to increase yield/plant (Table 1), therefore, it is an important character for improving maize yield potential. The highest kernels/cob (478.51) was recorded in IL 35 and it was significantly higher than other inbred lines, suggests superiority of the line for this character; breeders may consider the character during breeding programs. The character, 100-kernel weight though varied among the inbred lines in statistical sense, but variation was not remarkable, however, the highest 100-kernel weight (41.11 g) was obtained from the line IL35 and it was statistically similar to the line, IL 5 with 39.56 g; other lines were significantly lower than the two lines for the character.Source capacity is determined by the photosynthetic activity of the crop and by the availability of carbohydrate reserves and variation in final kernel weight reflects the interaction between source capacity and sink strength [31]. The resultant character, yield/plant was found the highest in IL35 with 477.02 g, which significantly higher than the yield production by other inbred lines. The second rank yield/plant was recorded from IL 32 with 451.10 g, which was significantly higher than the other thirteen inbred lines. The yield was increased in these inbred lines due to increase of kernels per cob as well as size of kernels [32,33] and the results of present study are favorably compared with the findings reported by [34, 35, 36, 37, 38, 39]. In conventional breeding, always interested to consider the final product like yield potential, therefore, the lines, IL35, IL 32 or even the third rank lines, like IL15 with 401.90 g/plant and IL 33 with406.49 g/plant might exploit in future breeding programs to improve maize yield potential.

### 3.2 Contribution of roots and leaves during crop growth

High yield potential is directly related to high depth of root system [40], this information may apply to assess relationship of root system with shoot growth in maize inbred lines, necessary for breeding programs.

**Table 1: Mean performance of yield and yield contributing characters of maize inbred lines**

| Treatment | Plant height(cm) | Leave length(cm) | Cob length(cm) | Cob diameter(cm) | Cob weight(g) | Kernels/cob | 100 kernel weight | Yield/plant (g) |
|---|---|---|---|---|---|---|---|---|
| IL1 | 214.00 cd | 65.77c | 17.11 c-d | 4.43cd | 145.88 f | 288.21 f | 38.24b | 320.08 f |
| IL3 | 214.66 cd | 71.33b | 15.87 d-f | 4.57 a-c | 161.23e | 324.77e | 38.29 b | 349.69 e |
| IL5 | 229.53 ab | 73.67ab | 14.75 f | 4.60 a-c | 186.78c | 392.00c | 39.56 a | 155.40 j |
| IL6 | 224.83bc | 66.00c | 17.04 c-d | 4.27e | 136.79 g | 275.33f | 37.11 de | 304.31 g |
| IL7 | 214.66 cd | 73.00ab | 19.17c | 4.59 a-c | 161.20e | 329.33e | 38.19 bc | 351.80 e |
| IL11 | 229.16 ab | 72.00b | 14.89 e-f | 4.57 a-c | 105.72i | 211.07gh | 36.69 ef | 254.81 h |
| IL15 | 211.33 e | 71.33b | 21.83a | 4.60ab | 187.61c | 394.07 c | 38.29 b | 401.90 c |
| IL21 | 228.66 b | 72.07b | 16.17 d-e | 4.45c | 89.99 i | 179.44 h | 36.60 ef | 245.09 h |
| IL22 | 214.06 cd | 72.00b | 17.50c-d | 4.53 a-c | 157.85e | 319.67e | 38.35 b | 345.31 e |
| IL23 | 216.53 c | 64.71 c | 10.17 g | 4.31 e | 117.49h | 230.33g | 37.49 cd | 192.13 j |
| IL26 | 233.33 a | 72.47a | 17.26 c-d | 4.30de | 154.72e | 331.67e | 35.89 f | 220.69 i |
| IL30 | 213.16 d | 73.83ab | 17.91 c-d | 4.51 bc | 173.99 d | 360.96 d | 38.31 b | 376.68 d |
| IL32 | 212.43 de | 74.71 ab | 20.18 b | 4.33 bc | 211.11 b | 454.11 b | 38.93b | 451.10 b |
| IL33 | 211.80 e | 74.52 ab | 21.07a | 4.81 a | 187.72c | 401.55 c | 38.15bc | 406.49 c |
| IL35 | 211.73 e | 76.11 a | 21.11 a | 4.75 a | 239.31 a | 478.51 a | 41.11a | 477.02 a |
| LSD(0.05) | 7.10 | 3.54 | 4.12 | 2.14 | 8.33 | 19.18 | 1.17 | 14.69 |
| Mean | 218.66 | 71.57 | 17.47 | 4.51 | 161.16 | 331.41 | 38.08 | 323.5 |

Here, IL=Inbred line

The mean values having same letter (s) were not different significantly at 5% level of probability.

Root length along with number of leaves/plant were recorded at 4 different stages of crop growth, like 30DAP, 45DAP, 60DAP and 75 DAP. The results presented in Table 2 revealed that there was a harmony between root length and leaves/plant at different stages and the values increased with corresponding increase of DAP. Since roots function as carrier of water and nutrients from soil to different parts of shoot, increase in root length suggests absorption of water and nutrients from different levels of soil. Furthermore, the elongated roots provided mechanical support to protect the crop from lodging. However, at 75DAP, noticeable root length vs leaves/plant were revealed by the lines, IL32 (root length vs leaves/plant= 67.30 cm vs 24.10), IL33(root length vs leaves/plant= 61.16 cm vs 24.90) and IL35(root length vs leaves/plant= 62.71 cm vs 25.12) (Table 2). The results suggest that these three lines provided strong mechanical support to keep the plants erect at pre-flowering stage of crop growth. Besides, long roots synthesized more cytokinins which later on translocated to different parts of shoot. There is a high scope to isolate desirable inbred lines against lodging considering long root length in maize [41].

**Table 2: Root length vs Number of leaves/plant estimates at different days after planting of maize inbred lines**

| Genotypes | 30 DAP | | 45 DAP | | 60 DAP | | 75 DAP | |
|---|---|---|---|---|---|---|---|---|
| | RL | NLPP | RL | NLPP | RL | NLPP | RL | NLPP |
| IL1 | 18.60 e | 7.76 de | 32.00 c-f | 11.33 de | 42.86 de | 16.33 bc | 63.16 f | 21.27 d |
| IL3 | 20.58 e | 7.12 de | 32.43 c-e | 12.00 cd | 43.83 c-e | 16.00 c | 65.16 d-f | 19.61 e |
| IL5 | 16.06 f | 5.91 f | 30.66 e-g | 10.00 g | 41.83 e | 13.00 f | 61.88 f | 17.28 g |
| IL6 | 19.74 e | 7.33 c-e | 33.20 bc | 11.33 de | 44.20 b-d | 14.67 d | 65.33 d-f | 18.00 fg |
| IL7 | 21.66 c-e | 7.67 b-d | 34.80 ab | 12.33 c | 45.70 a-c | 14.67 d | 69.80 bc | 17.90 fg |
| IL11 | 17.33 f | 6.00 f | 31.20 d-f | 10.33 fg | 42.43 de | 13.33 ef | 62.40 f | 17.96 fg |
| IL15 | 23.16 ab | 8.22 a-c | 35.11 a | 14.10 a | 55.40 a | 17.33 b | 79.19 a-b | 13.20 h |
| IL21 | 21.56 c-e | 6.67 ef | 31.90 c-f | 10.88 ef | 42.50 de | 13.67 d-f | 67.80 b-e | 18.67 ef |
| IL22 | 21.10 de | 7.37 c-e | 33.83 bc | 11.33 de | 46.20 ab | 14.33 de | 64.80 d-f | 18.33 f |
| IL23 | 15.89 f | 7.07 de | 29.20 gh | 11.33 de | 42.00 de | 16.00 c | 64.31 ef | 21.90 cd |
| IL26 | 21.16 de | 6.67 ef | 33.83 bc | 11.21 ef | 45.96 a-c | 16.00 c | 67.26 c-e | 21.00 d |
| IL30 | 22.00 b | 7.16 b-d | 33.03 b-d | 11.67 c-e | 44.06 b-e | 17.00 bc | 68.53 b-d | 22.11 cd |
| IL32 | 22.54 b | 7.44 b-d | 28.53 h | 12.11 c | 34.80 f | 17.00 bc | 67.30 c-e | 24.10 b |
| IL33 | 24.19 bc | 9.11 a | 28.46 h | 13.61 b | 34.95 f | 19.67 a | 61.16 ab | 24.90 b |
| IL35 | 26.00 a | 8.19 ab | 31.26 fg | 13.14 b | 37.00 f | 19.88 a | 62.71 a | 25.12 a |
| LSD(0.05) | 2.37 | 0.88 | 1.28 | 0.91 | 2.11 | 1.31 | 3.44 | 1.81 |
| Mean | 20.77 | 7.32 | 31.96 | 11.78 | 42.38 | 15.92 | 66.05 | 20.09 |

Here, RL= Root length, NLPP= Number of leaves/plant, DAP= Days after planting

### 3.3 Study on genetic parameters of different characters of maize inbred lines

From the Table 3 it is revealed that difference between genotypic coefficient variation and phenotypic coefficient of variation for a particular character was very close, suggests inherent genetic potential of the inbred lines to express the characters but variation might be created by changing the growing condition. Heritability estimates were higher for the character like, 100-kernel weight (86.33%), followed by cob length (84.27%) but none of the character showed appreciable heritability coupled with genetic advance, suggests low progress under selection in the evaluated inbred lines. Analysis of variance pertaining to plant height revealed highly significant differences among the maize inbred lines [42, 43]. High heritability coupled with a high range of genotypic coefficient of variation (GCV) and phenotypic coefficient of variation (PCV) for plant height suggests that genetic improvement might be achieved through simple selection for the character [44, 45,46]. [47] studied two sets of maize inbred lines and found that both heritability and genetic advance estimates were higher for grain yield and plant height, hence additive gene action was depicted. High heritability along with high genetic advance was reported by [48] for plant height and grain yield. [49] recorded high heritability with high genetic advance for 100-seed weight in maize. Whatever, heritability against yield/plant and genetic advance even as percentage of mean were lower in magnitudes, invariably indicates yield was influenced by yield influencing characters along with growing condition. Breeding method may apply for discriminant function to integrate appropriate character in selection to get gain in next generation.

**Table 3: Estimates of coefficients of variation, heritability in broad sense, genetic advance and genetic advance in percentage of mean for various characters in maize inbred lines**

| Characters | Mean | Coefficient of variation (%) | | Heritability in broad sense (%) | Genetic advance | Genetic advance as percent of mean |
|---|---|---|---|---|---|---|
| | | Genotypic | Phenotypic | | | |
| PH | 218.66 | 10.35 | 11.47 | 67.77 | 14.56 | 21.09 |
| LL | 71.57 | 4.96 | 5.79 | 73.5 | 20.12 | 8.77 |
| CL | 17.47 | 22.97 | 23.66 | 84.27 | 8.82 | 45.95 |
| CD | 4.51 | 2.79 | 3.35 | 69.12 | 1.44 | 4.77 |
| CW | 161.16 | 23.95 | 24.09 | 68.77 | 2.59 | 49.02 |
| KPC | 331.41 | 25.34 | 26.59 | 78.02 | 20.96 | 51.68 |
| HKW | 38.08 | 2.72 | 3.93 | 86.33 | 8.29 | 5.21 |
| YPP | 323.5 | 37.74 | 38.33 | 68.99 | 2.08 | 57.34 |

Here, PH= Plant height, LL= Leave length, CL = Cob length, CD = Cob diameter, CW = Cob weight, KPC = Kernel per cob, HKW = Hundred kernel weight and YPP = Yield per plant.

### 3.4 Characters association and partitioned of association in relation to yield

Correlation coefficients were measured both at genotypic and phenotypic levels (Table 4). The results where genotypic correlation coefficient was higher than corresponding phenotypic correlation coefficient suggest inherent potential of the inbred lines to make such association between the pair of characters concerned, while phenotypic correlation coefficient was higher than corresponding genotypic correlation coefficient, suggest the association may be changed upon changing the growing conditions. All the yield related characters showed positive and significant both at genotypic and phenotypic levels, except plant height, which exhibited negative and non-significant association with yield/plant.Plant height had significant but negative correlation with the yield at both genotypic and phenotypic level [50].A significant correlation was revealed between plant height and grains per cob [51].

**Table 4: Genotypic ($r_g$) and phenotypic ($r_p$) correlation coefficient among pairs of characters in maize inbred lines**

| Characters | LL | | CL | | CD | | CW | | KPC | | HKW | | YPP | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $r_g$ | $r_p$ | $r_g$ | $r_p$ | $r_g$ | $r_p$ | $r_g$ | $r_p$ | $r_g$ | $r_p$ | $r_g$ | $r_p$ | $r_g$ | $r_p$ |
| PH | 0.63 | 0.91 | -0.72* | -0.81* | -0.54 | -0.77 | -0.69* | -0.57* | -0.7* | -0.21* | -0.43* | -0.62* | -0.79 | -0.48 |
| LL | | | 0.52** | 0.89** | 0.59 | 0.37 | 0.62* | 0.28* | 0.63** | 0.81** | 0.41* | 0.72* | 0.56** | 0.70** |
| CL | | | | | 0.49* | 0.71* | 0.66** | 0.69** | 0.68** | 0.35** | 0.4 | 0.11 | 0.69** | 0.53** |
| CD | | | | | | | 0.51** | 0.45** | 0.49** | 0.72** | 0.56 | 0.24 | 0.57** | 0.55** |
| CW | | | | | | | | | 0.99** | 0.65** | 0.76** | 0.35** | 0.81** | 0.89** |
| KPC | | | | | | | | | | | -0.69 | -0.42 | 0.8** | 0.88** |
| HKW | | | | | | | | | | | | | 0.6** | 0.79** |

**Indicate significant at 5% level of probability

Here, PH= Plant height, LL= Leave length, CL = Cob length, CD = Cob diameter, CW = Cob weight, KPC = Kernel per cob, HKW = Hundred kernel weight and YPP = Yield per plant.

The results suggest that the selected characters, except plant height had prominent effect on increasing yield/plant maize inbred lines. Since genotypic variation and environmental variation are covered by phenotypic variation, only phenotypic correlation coefficients of different characters with yield/plant were portioned into direct and indirect effects (Table 5) and the cause and effect of the characters are presented by the Fig 1. Among the selected characters, cob diameter exerted maximum direct effect (0.86273), followed by cob length (0.82606) and kernels/cob (0.77719) [52] reported positive direct of cob diameter on yield/plant in maize. [53] reported that cob length had high positive direct effects on grain yield. Furthermore, cob length (cm) and cob diameter (mm) had direct and positive effect on grain yield per plant [54]. The negative indirect effect of plant height was not counter balanced and compensated by other indirect effects exerted by other characters that eventually developed negative and non-significant correlation with yield/plant. Plant height showed negative direct effect on grain yield per plant [55]. The residual effect was only 0.039, suggests that 96.1% variation had included during path analysis of the characters.The source-sink relationship during kernel development period is the key information in selection of superior maize genotypes [56] and this information is relevant to identify optimal methods for crop modelling and to select breeding strategies [57].

**Table 5: Phenotypic path coefficients of different characters with correlation coefficients ($r_p$) of different characters of maize inbred lines**

| Characters | PH | LL | CL | CD | CW | KPC | HKW | YPP |
|---|---|---|---|---|---|---|---|---|
| PH | **-0.7021** | 0.36972 | 0.61955 | -0.1435 | -0.2133 | -0.2678 | -0.14132 | -0.48 |
| LL | -0.8725 | **0.52073** | -0.1709 | 0.62115 | 0.20718 | 0.26403 | 0.13249 | 0.70** |
| CL | -0.6766 | 0.29682 | **0.82606** | -0.509 | 0.20414 | 0.25649 | 0.13249 | 0.53** |
| CD | -0.7644 | 0.37493 | -0.4874 | **0.86273** | 0.17367 | 0.20745 | 0.18254 | 0.55** |
| CW | -0.9215 | 0.2541 | 0.21346 | 0.19174 | **0.74468** | 0.21342 | 0.19436 | 0.89** |
| KPC | -0.8925 | 0.16451 | 0.26172 | 0.19449 | 0.20163 | **0.77719** | 0.17567 | 0.88** |
| HKW | -0.849 | 0.03433 | 0.12173 | 0.17488 | 0.25289 | 0.29044 | **0.76441** | 0.79** |

Residual effect=0.039

The bold figures in the diagonal indicate direct effects and other figures are indirect effects

Here, PH= Plant height, LL= Leave length, CL = Cob length, CD = Cob diameter, CW = Cob weight, KPC = Kernel per cob, HKW = Hundred kernel weight and YPP = Yield per plant.

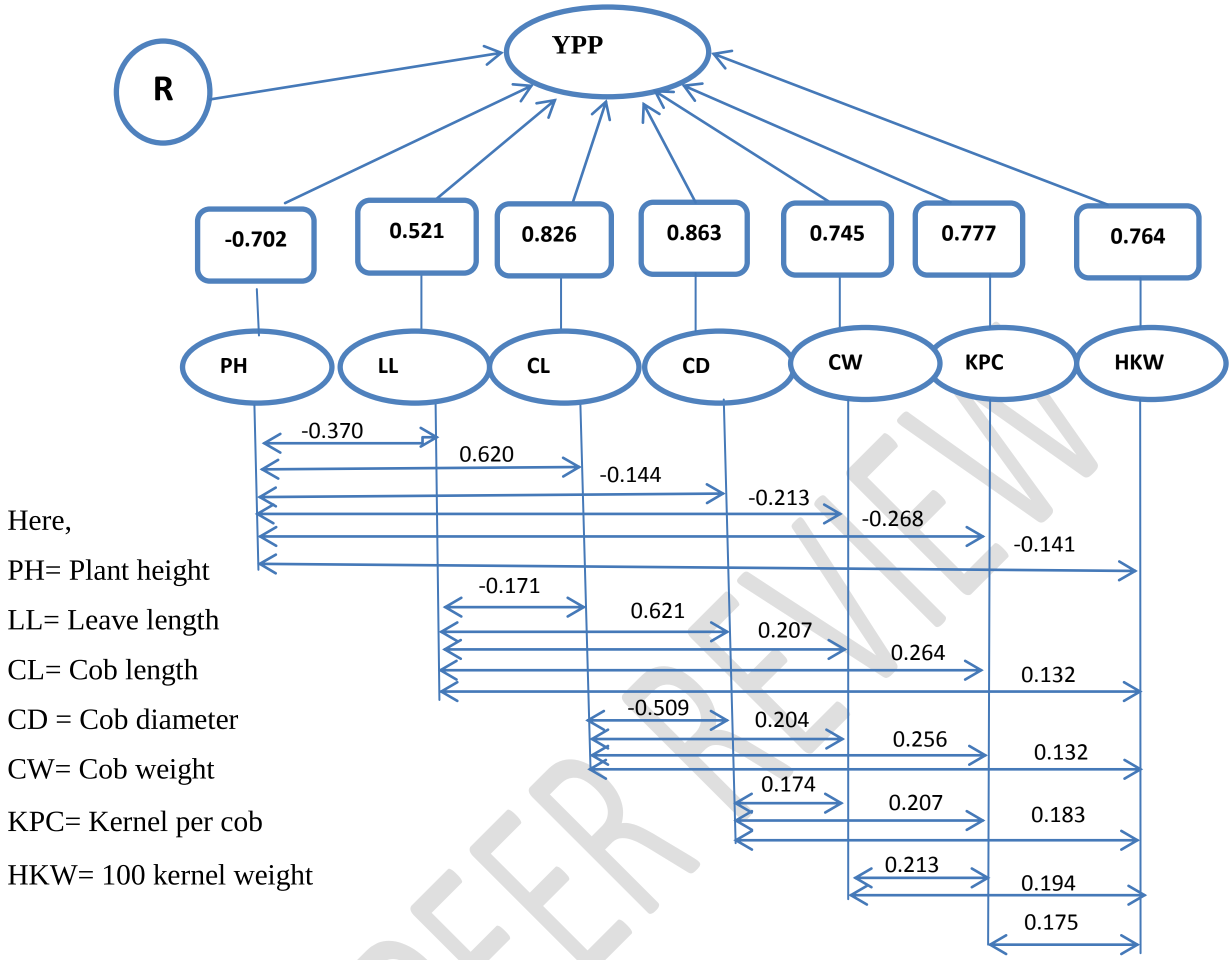


Figure 1: Path diagram showing yield contributing characters on yield per plant in maize

## 4. CONCLUSION.

In Bangladesh the area under hybrid maize cultivation is increasing due it's high yield and reasonable market price as compared to other crops. The agricultural entrepreneurs are showing interest to invest capital in this sector but most of the hybrid seeds are importing from China, India and Thailandexpending huge amount of foreign currency every year. Our locally developed hybrids are still low yield potential compared to exotic hybrids. Due to want of outstanding parental lines different agencies of Bangladesh are yet not become successful to produce a hybrid exceeding the demand of the farmers for foreign hybrid seeds. Considering these issues, superior parental lines have been developed to have better combinations for the development of outstanding hybrid maize varieties.A consistent contribution of kernel yield components and source-sink relationship became more limiting in rainfed condition, suggest optimized irrigation during kernel filling stage of the inbred lines of maize. Finally, it is concluded, the inbred lines appeared as promising may exploit either by developing hybrid varieties and synthetic varieties in future through applying appropriate breeding programs for enhancing yield potential of hybrid maize cultivation in Bangladesh.

**REFERENCES**


1. Patil SM, Kumar K, Jakhar DS, Rai A, Borle UM, Singh P. Studies on variability, heritability, genetic advance and correlation in maize (*Zea mays* L.). International Journal of Agriculture, Environment and Biotechnology. 2016; 9(6): 1103-1108.
2. Uddin H, Rashid MHA, Akhter S. Relative Profitability of Maize Production under Different Farm Size Group in Kishoregonj District of Bangladesh. Agric. 2010; 21(1 & 2): 247–248.
3. Gupta HS, Agrawal PK, Mahajan V, Bisht GS and Kumar A, et al. Quality protein maize for nutritional security: Rapid development of short duration hybrids through molecular marker assisted breeding. Curr. Sci. 2009; 96: 230-237.
4. Prasanna BM, Vasal SK, Kassahun B and Singh NN. Quality protein maize. Curr. Sci. Assoc. 2001; 81: 1308-1319.
5. Bangladesh Bureau of Statistics (BBS). Yearbook of Agricultural Statistics-2018. 28th Series. Statistics and Informatics Division (SID). Ministry of Planning Government of the People's Republic of Bangladesh. 2019.
6. Bangladesh Bureau of Statistics (BBS). Yearbook of Agricultural Statistics-2017. 28th Series. Statistics and Informatics Division (SID). Ministry of Planning Government of the People's Republic of Bangladesh. 2018.
7. Bangladesh Bureau of Statistics (BBS). Yearbook of Agricultural Statistics-2016. 28th Series. Statistics and Informatics Division (SID). Ministry of Planning Government of the People's Republic of Bangladesh. 2017
8. M. Shahbandeh. Corn production worldwide 2018/2019, by country.

Apr 27, 2020.

9. Golbashy M, Ebrahimi M, Khorasani SK and Choukan R. Evaluation of drought tolerance of some corn (*Zea mays* L.) hybrids in Iran. African Journal of Agricultural Research. 2010; 5(19): 2714-2719.
10. Akbar M, Shakoor MS, Hussain A, Sarwar M. Evaluation of maize 3 way crosses through genetic variability, broad sense heritability, characters association and path analysis. Journal of agricultural research. 2008; 46(1):39–45.
11. FAO (Food and Agriculture Organisation). FAO corporate document repository: Economic and social development department. http://www.fao.agriculture/food/grain/ in/developing/countries.html. 2012. Accessed 14 April 2013.
12. Azad MAK, Biswas BK, Alam N and Alam SS. Genetic Diversity in Maize (*Zea mays* L.) Inbred Lines. The Agriculturists. 2012; 10(1): 64-70.
13. Taiwo OP, Nwonuala AI, Isaiah BF. Variability in yield and yield components of selected pro-vitamin a maize (Zea mays L.) Varieties in a Humid Environment of Port Harcourt, Nigeria. Asian Journal of Agricultural and Horticultural Research. 2020; 19:1-0.
14. Zhang H, Turner NC, Poole ML. Source–sink balance and manipulating sink–source relations of wheat indicate that the yield potential of wheat is sink-limited in high-rainfall zones. Crop and Pasture Science. 2010; 61(10): 852-861.
15. Egile DB. Variation in leaf starch and sink limitations during seed filling in soybean. Crop Sci. 2000; 39: 1361-1368.
16. Burton WJ. Effects of defoliation on seed protein concentration in normal and high protein lines of soybean. Crop Sci. 2004; 72: 131- 139.
17. Bilgin O, Korkut KZ, Başer I, Dağlioğlu O, Öztürk I, Kahraman T and Balkan A. Variation and heritability for some semolina characteristics and grain yield and their relations in durum wheat (*Triticum durum*Desf.). World Journal of Agricultural Sciences. 2010; 6(3): 301-308.
18. Singh BD. Plant breeding: principles and methods. Kalyani publishers. 2015.
19. Rutkoski JE. Estimation of Realized Rates of Genetic Gain and Indicators for Breeding Program Assessment. Advance in Agronomy. 2019; 157: 217-249
20. Singh AK, Mishra SP, Parihar R. Studies on Genetic Variability Parameters on Grain Yield and Its Yield Attributing Characters in Maize (*Zea mays* L.). International Journal of Current Microbiology and Applied Sciences. 2018; 7(09): 2148-2150.

21. Hallauer AR, Miranda JB. Quantitative genetics in maize breeding. (2nd edn), Iowa State University Press, Iowa, Ames, USA. 2016.
22. Dewey DR, Lu KA. Correlation and Path-Coefficient Analysis of Components of Crested Wheatgrass Seed 1. Agronomy Journal. 2017; 51: 515-518.
23. Cochran WG, Cox GM. Experimental designs.2nd edition wiley, New York. 1960.
24. Gomez KA, Gomez AA. Statistical Procedure for Agricultural Research (2nd edition). International Rice Research Institute. A Willey International Science publication. 1984; 28-192.
25. Johnson HW, Robinson HF, Comstock RE. Estimates of genetic and environmental variability in soybeans. Agron. J. 1955; 47(7): 314-318.
26. Singh RK, Chaudhary BD. Biometrical methods in quantitative genetic analysis. Biometrical Methods in Quantitative Genetic Analysis. 1979; x + 304.
27. Allard R. Principles of plant breeding. John Wiley and Sons Inc., New York. 1975.
28. Comstock R, Robinson H, Gowen, J. Estimation of average dominance of genes, Heterosis, 1952; 494-516.
29. Seebauer JR, Singletary GW, Krumpelman PM, Ruffo ML, Below FE. Relationship of source and sink in determining kernel composition of maize. Journal of experimental botany. 2010 ;61(2):511-9.
30. Rathore DM, Singh K, Singh BP. Effect of nitrogen and plant population on the yield attributes of maize. Indian J. Agric. Res. 1976; 10(2): 79-82.
31. Shekoofa A, Emam Y, Pessarakli M. Source-sink manipulation effects on maize kernel quality. Journal of plant nutrition. 2013;36(9):1401-11.
32. Borrás L, Slafer GA, Otegui ME. Seed dry weight response to source–sink manipulations in wheat, maize and soybean: a quantitative reappraisal. Field Crops Res. 2004; 86: 131–146.
33. Rao IM, Beebe SE, Polania J, Grajales M, Cajiao C, Ricaurte J, et al. Evidence for genotypic differences among elite lines of common bean in the ability to remobilize photosynthate to increase yield under drought. J. Agric. Sci. 2017; 155: 857–875.
34. Simenov N, Tsankova G. Effect of fertilizers and plant density on yield of maize hybrids with two years. (In Bularian). Rasteniev'dni-Nauki. 1990; 27(8): 14-18.

35. Narayanaswamy MR, Veerabadran V, Joyanthi C, Chinnuswammy C. Plant density and nutrient management for rainfed maize in red soil. Madras Agril. J. 1994; 81(5): 248-251.
36. Hassen H. Effect of defoliation on yield components of maize and under sown forage. Agri. Topica. 2003; 18(1/2): 5-7.
37. Zewdu T. Effect of defoliation and intercropping with forage legumes on maize yield and forage production. Trop. Sci. 2003; 43(4): 204-207.
38. Li-Xiangjun, AnpingInanaga S, Enejj AE, Ali AM. Mechanisms promoting recovery from defoliation in determinate and indeterminate soybean cultivar. J. Food Agric. Env. 2005; 3(3/4):178-183.
39. Chaudhary AN, Latif MI, Haroon, Ur-Rasheed M, Jilani G. Profitability increase in maize production through fertilizer management and defoliation under rain fed cropping. Int. J. of Bio.and Biotech. 2005; 2(4): 1007-1012.
40. Koffler NF. A profundidade do sistema radicular e o suprimento de águaàsplantas no Cerrado**.** Piracicaba: POTAFOS, 1986; 12 p. (InformaçõesAgronômicas, 33).
41. Bray AL, Topp CN. The quantitative genetic control of root architecture in maize. Plant and Cell Physiology. 2018; 59(10): 1919-1930.
42. Noor M, Rahman H, Durrishahwar MI, Shah SMA, Ullah I. Evaluation of maize half-sib families for maturity and grain yield attributes. Sarhad Journal of Agriculture. 2010; 26: 545-549.
43. Stromberg DC, Campton WG. Ten cycles of full-sib recurrent selection in maize. Crop Sciences. 1989; 29: 1170-1172.
44. Mahmood Z, Malik SR, Akhtar R, Rafique T. Heritability and genetic advance estimates from maize genotypes in ShishiLusht a valley of Krakurm. International Journal of Agriculture and Biology. 2014; 6: 790-791.
45. Mustafa HS, Ahsan M, Aslam M, Ejaz-ul-Hasan QA, Bibi T, Mehmood T. Genetic variability and traits association in maize (*Zea mays* L.) Accessions under drought stress. Journal of Agriculture Research.2013; 51: 231-238.
46. Vashistha A, Dixit NN, Dipika, Sharma SK, Marker S. Studies on heritability and genetic advance estimates in Maize genotypes. Bioscience Discovery. 2013; 4: 165-168.
47. IIyas M, SA Khan, Awan SI, Rehman S. Assessment of heritability and genetic advance in maize (*Zea mays* L.) under natural and water stress conditions. Sarhad Journal of Agriculture. 2019; 35(1): 144-154.

48. Kinfe H. Tsehaye Y. Studies of heritability, genetic parameters, correlation and path coefficient in elite maize hybrids. Academic Research Journal of Agricultural Science and Research, 2015; 3(10): 296-303.
49. Bekele A, Rao TN. Estimates of heritability, genetic advance and correlation study for yield and its attributes in maize (*Zea mays* L.). Journal of Plant Sciences. 2014; 21: 4-6.
50. Khatun F, Begum S, Motin A, Yasmin S, Islam MR. Correlation coefficient and path analysis of some maize (Zea mays L.) hybrids. Bangladesh J. Bot.1999; 28: 9–15.
51. Alaei, Y. Correlation analysis of corn genotypes morphological traits. International Research Journal of Applied and Basic Sciences. 2012; 3: 2355-2357.
52. Prakash R, Ravikesavan R, Vinodhana NK, Senthil A. Genetic variability, character association and path analysis for yield and yield component traits in maize (*Zea mays* L.). Electronic Journal of Plant Breeding. 2019; 10(2): 518-524.
53. Munawar M, Shahbaz M, Hammad G, Yasir M. Correlation and path analysis of grain yield components in exotic maize (*Zea mays* L.) hybrids. International Journal of Sciences: Basic and Applied Research. 2013; 12(1): 22-27.
54. Huda MN, Hossain MS, Sonom M. Genetic variability, character association and path analysis of yield and its component traits in maize (*Zea mays* L.). Bangladesh Journal of Plant Breeding and Genetics. 2016; 29(1): 21-30.
55. Selvaraj CI, Nagarajan P. Interrelationship and path-coefficient studies for qualitative traits, grain yield and other yield attributes among maize (*Zea mays* L.). International Journal of Plant Breeding and Genetics. 2011; 5(3): 209-223.
56. Bonelli LE, Monzon JP, Cerrudo A, Rizzalli RH, Andrade FH. Maize grain yield components and source-sink relationship as affected by the delay in sowing date. Field Crops Research. 2016; 198:215-25.
57. Hall AJ.Wither crop physiology? In ‘Crop physiology: applications for genetic improvement and agronomy’. (Eds V Sadras, D Calderini). 2009;545–570.