Original Research Article

Source-sink potential of maize inbreds grown in rainfed condition

Abstract

With a view to select desirable maize inbred lines, 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 RCBD with three replications. The individual plot size and spacing were 2m x 3m and 40cm x 60 cm respectively. The experimental materials comprised fifteen inbred lines. The quantitative characters like 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, IL15, Il32, 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. Out of seven selected characters, only plant height showed negative correlation with yield/plant, hence short stature plant is suitable for maize cultivation. The phenotypic correlation coefficients were partitioned into direct and indirect effects. 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 IL35 seemed to be promising for future breeding programs.

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 (*Zea maxicana*) 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 20^0C to 30^0C, prevailing in our country. In the year 2017-2018, the United States was the largest producer of maize with a production of 370.96 million metric tons 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 [8] because of its multifarious use and high quantity grain yield per unit area [9] is contributing billions of dollars to the global economy [10]. 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 [11].

The 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 [12]. In addition, rapid maturation followed by bending down of leaves, indicate minimal photosynthetic product, sugar, is the principal source for the sink (kernels) [13], the physiological state of kernels ultimately suffers from possible utilization of sugar [14], which leads to develop infertile kernels in the cobs.

The efficiency of selection depends upon heritability and the genetic advance of individual character [15] 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 [16]. 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 [17]. In path coefficient analysis, grain yield is considered as dependent variable and the remaining characters are considered as independent variables [18]. 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 [19] and cause effects of the components are to be assessed through appropriate biometrical tools [20]. 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 April 2019. 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 RCBD with three replications. The unit plot size and spacing were 3m x5m and 20cm x 60cm respectively. All agronomic requirements after seed sowing were 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 [21]. 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 [22]. Genetic parameters were estimated following the method proposed by [23] and correlation coefficient and path coefficient were estimated according to [24]. Genetic advance was calculated following formula given by [23] and [25] and as percent of mean by the formula of [26].

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 charters are 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). 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 [27]. 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. 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 [28, 29] and the results of present study are favorably compared with the findings reported by [30, 31, 32, 33, 34, 35]. 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 IL406.49 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 [36], 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	65.77 c	17.11 c-d	4.43 cd	145.88 f	288.21 f	38.24 b	320.08 f
IL3	214.66 cd	71.33 b	15.87 d-f	4.57 a-c	161.23 e	324.77 e	38.29 b	349.69 e
IL5	229.53 ab	73.67 ab	14.75 f	4.60 a-c	186.78 c	392.00 c	39.56 a	155.40 j
IL6	224.83 bc	66.00 c	17.04 c-d	4.27 e	136.79 g	275.33 f	37.11 de	304.31 g
IL7	214.66 cd	73.00 ab	19.17 c	4.59 a-c	161.20 e	329.33 e	38.19 bc	351.80 e
IL11	229.16 ab	72.00 b	14.89 e-f	4.57 a-c	105.72 i	211.07 gh	36.69 ef	254.81 h
IL15	211.33 e	71.33 b	21.83 a	4.60 ab	187.61 c	394.07 c	38.29 b	401.90 c
IL21	228.66 b	72.07 b	16.17 d-e	4.45 c	89.99 i	179.44 h	36.60 ef	245.09 h
IL22	214.06 cd	72.00 b	17.50 c-d	4.53 a-c	157.85 e	319.67 e	38.35 b	345.31 e
IL23	216.53 c	64.71 c	10.17 g	4.31 e	117.49 h	230.33 g	37.49 cd	192.13 j
IL26	233.33 a	72.47 a	17.26 c-d	4.30 de	154.72 e	331.67 e	35.89 f	220.69 i
IL30	213.16 d	73.83 ab	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	38.93 b	451.10 b
IL33	211.80 e	74.52 ab	21.07 a	4.81 a	187.72 c	401.55 c	38.15 bc	406.49 c
IL35	211.73 e	76.11 a	21.11 a	4.75 a	239.31 a	478.51 a	41.11 a	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 cytokinnis 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 [37].

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 [38, 39]. High heritability coupled with a high range of GCV and PCV for plant height suggests that genetic improvement might be achieved through simple selection for the character [40, 41,42]. [43] 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 [44] for plant height and grain yield. [45] 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 [46]. A significant correlation was revealed between plant height and grains per cob [47].

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) [48] reported positive direct of cob diameter on yield/plant in maize. [49] 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 [50]. 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 [51]. The residual effect was only 0.039, suggests that 96.1% variation had included during path analysis of the characters.

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.

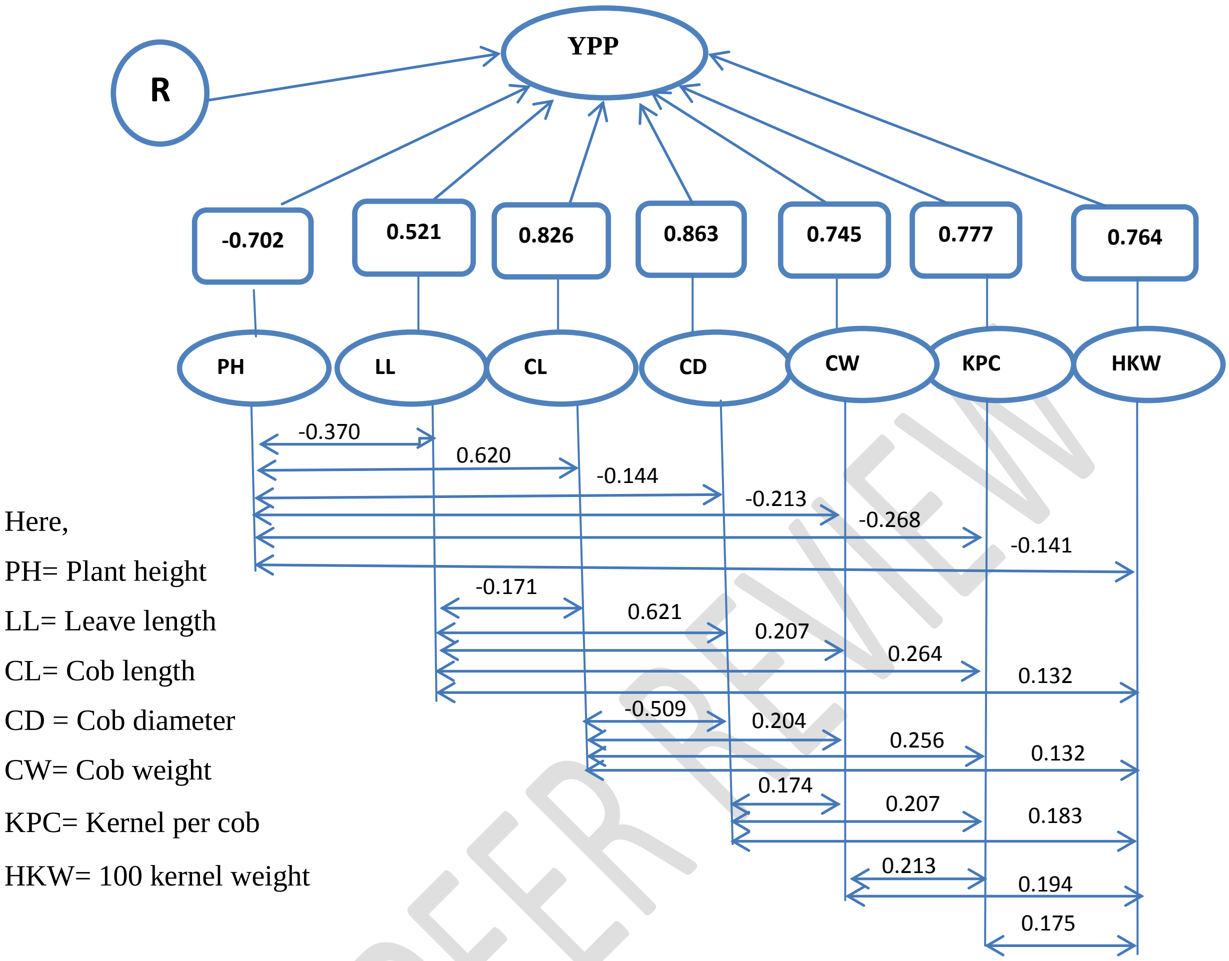

Figure 1: Path diagram showing yield contributing characters on yield per plant in maize

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 Thailand expending 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. 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.

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