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Polygenic Variations and Character Association Studies in Garlic

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Authors' contributions

This work was carried out in collaboration between all authors. All authors read and approved the final manuscript.

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ABSTRACT

Garlic contains several important constituents like garlicin and allistatin. Besides it is used as spices it has several medicinal properties. Despite high demand of the crop, there is a huge gap between production and uses because of low yield potentiality. Therefore to identify high yielding variety twenty-seven genotypes of garlic were evaluated for twelve quantitative characters during the present investigation. Genotype 644 was found the highest yielder than standard check variety (G282) used. A high value of GCV (Genotypic coefficient of variation) and PCV (phenotypic coefficient of variation) were recorded for clove weight, yield per plant and cloves per bulb. It was observed that the plant height, leaf length and yield per plant were the main contributors for high heritability. The genetic gain was effective in yield per plant, the weight of clove, cloves per bulb and leaf length. Almost all morphological characters were positively correlated with yield per plant. Plant height, average clove weight and clove length directly affect the yield of garlic, clove width cloves per bulb, leaf width has indirect effects on yield. Variability present in a population is paramount importance to plant breeder for starting a judicious crop improvement programme.

Keywords: Allium sativum; genotypic correlation; genotypic coefficient of variation; heritability; phenotypic correlation; phenotypic coefficient of variation; variability.

1. INTRODUCTION

Garlic belongs to family Alliaceae [1], has its origin in central Asia. Garlic is grown in India in an area of 280.95 ha having a production of 1617.34 MT and productivity of 5.76 MT/ha, whereas in Bihar garlic is grown in an area of 4.25 ha area having a production 4 MT with least

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productivity potential 0.94 MT/ha from national productivity as Punjab (state) known for highest productivity at 11.41 T/ha (NHRDF, 2015). Low yield performance of garlic genotypes was found because of traditional growing genotypes with unknown potentiality, this phenomenon attributed to decline in per garlic cultivation by farmers in the rural area and increase in labour out-migration from Bihar to another state or the country. Despite the decline of cultivation it is well-known fact about the Bihar that agro-ecological situation is quite favourable for the production of agricultural and horticultural crops. Stagnation in horticultural productivity and an increase in input prices, crop production turns to be losing business for Bihar farmers. Information about the magnitude of genetic variability present in the genetic stocks, heritability and genetic advance among various traits are used in the breeding of Garlic (*Allium sativum* L.) [2]. Characterisation of genotypes helps to ensure efficient and effective use of genotypes for further crop improvement. Heritability and genetic advance are complementary concepts and important to the selection process. Genetic advance provides information of expected genetic gain resulting in the selection of superior genotypes. Knowledge of association of different components, together with their relative contributions, is important in selection. The correlation coefficient indicates the inter-relationship of characters and does not furnish information on the cause of the effect. Separation of correlation of coefficient into components of direct and indirect effect through path analysis is important. Variability is a keystone to the breeders to develop high yielding and stable cultivars through selection, from the existing genotypes. Because garlic does not produce a flower, breeders cannot breed and develop cultivars specific to growing regions that enhance farmer's production. So, garlic can be improved by selection. The present study was conducted to investigate associations among components and their direct and indirect contribution to bulb yield in garlic by keeping yield enhancement objectives like study the variability in the existing genotypes and establish interrelationship among various attributes under study [3]. This study will help the breeder in the determination of good character for yield enhancement.

2. MATERIALS AND METHODS

The investigation was conducted at the Department of Horticulture (Vegetable and Floriculture), Bihar Agricultural University, Sabour, Bhagalpur, Bihar, India, during winter season 2014-2015. All garlic genotypes, collected from districts/regions, as well as from Directorate of onion and garlic research, Pune. The investigation was arranged in a Randomised Complete Block Design (RCBD) replicated 3 times. Alluvial soil covers a maximum area of Bhagalpur. The experimental plot was ploughed once to attain fine filth. The farmyard manures were applied @ 150q/ha. Nitrogen, phosphorous, and potash was applied in the form of urea, single superphosphate, and murate of potash respectively. One-third dose of nitrogen was applied along with a full dose of phosphorous and potash at the time of final field preparation and remaining dose of nitrogen was applied in two split doses as top dressing at an interval of one month from the date of sowing. The crop is irrigated 7-10 days interval depends on moisture availability. Individual cloves were sown in line sowing method. The spacing plant to plant and row to row was 10 × 15 cm. Observation were recorded on the quantitative traits; plant height, leaf length, number of leaves per plant, leaf width, neck thickness, bulb polar diameter, bulb equatorial diameter, number of cloves per bulb, clove length, clove width, clove weight, and yield per plant.

2.1 Statistical Analysis

The data were subjected to analysis of variance according to Panse and Sukhatme (1967). Genotypic and phenotypic coefficients of variations were analysed following Burton and De vane [4]. Heritability in a broad sense, and expected genetic advance, as percent of the mean, were calculated using the method of Johnson et al. [5]. Character association of the morphological traits were analysed following Dewey and Lu [6]. Correlation helps to measure and analyze the degree of relationship between two variables by Al-Jibouri et al. [7].

3. RESULTS AND DISCUSSION

Mean performances of genotypes and checks for all the traits varied (Table 1). Maximum plant height was found for genotype IC-375119 and shortest was for RG-464. The most leaves were for BRG-10 followed by 644; the fewest for IC-375107. The fewest leaves per plant were for WG 7-1, WG 7 and IC-375107. Leaves were longest for genotype 644 followed by IC-375119 and the shortest leaves were for genotype WG-7-1. The widest leaves were for BRG-8andthe narrowest leaves were for genotypes 543 and WG-2. Neck thickness was greatest for 644

followed by WG 7-1; the thinnest neck was with genotype 569. The greatest polar bulb diameter was for 644 followed by BRG-14; the least polar diameter of the bulb was for genotype 453. Genotype 453 had the widest equatorial diameter followed by BRG-14. The least equatorial diameter was for WG-7. Genotype 644 had the longest cloves followed by genotype 4; WG 2had the shortest cloves. The widest cloves were for 569 followed by IC 375119; narrowest cloves were for genotype 527. The most number of cloves per bulb was in BRG-14 followed by 453, the fewest number of cloves per bulb was in genotype 569. The heaviest bulbs were in 644 followed by BRG-10; lightest bulbs weight was for cultivar RG 464. Genotypes studied in this experiment were found to be noble for all characters for genotypes and genotype 644 is heaviest yielder can be recommended for commercial cultivation in Bhagalpur conditions. Significant variation for all characters reported by Zahedi et al. [8]; Singh et al. [9]; Vatsyayan et al. [10]; Sonkiya et al. [11]; Esho (2015); Sengupta et al. [12]; Shree et al. [13] and Jogdande et al. [14].

3.1 Variability between Morphological Characters

For the characters studied phenotypic variance was higher than genotypic variance (Table 2). Maximum genotypic and phenotypic variance was for the weight of clove, yield per plant, number of cloves per bulb, leaf length, leaves per plant and plant height [15]. Low levels of genotypic and phenotypic variances observed for polar and equatorial bulb diameters, clove length and leaf width. Broad-sense heritability varied from a low for equatorial bulb diameter to high for clove width (Table 2). Clove width, plant height,

Table 1. Mean values for characters of garlic genotypes for variation during 2014-2015. Numbers present variation among genotypes for yield

Character/ genotype	PH	Le/P	LLe	BrLe	NTh	PDB	EDB	LC	WdC	C/B	AWC	Y/P
4	38.47	5.30	35.43	1.70	0.93	3.81	3.49	3.05	0.84	21.00	0.66	15.72
BRG-14	46.97	5.53	42.17	1.60	1.26	3.90	3.61	2.56	0.91	31.37	0.53	17.22
G-232	44.27	5.27	40.10	1.61	1.02	3.38	3.36	2.53	0.87	25.47	0.61	16.53
BRG-7	39.27	5.30	36.27	1.50	1.16	3.45	3.03	2.19	0.71	27.47	0.35	11.64
BRG-13	37.87	5.87	34.23	1.60	1.16	3.01	3.16	2.28	0.80	20.43	0.54	12.55
IC-345585	37.23	5.43	36.27	1.52	1.22	3.15	3.52	2.33	0.79	27.23	0.50	15.26
453	51.13	5.10	43.43	1.47	1.28	2.88	3.65	2.41	0.77	29.30	0.45	17.39
BRG-9	34.23	5.73	29.53	1.63	1.33	3.24	3.35	2.44	0.74	28.67	0.42	16.65
644	44.67	7.63	47.97	1.77	1.37	3.93	3.43	3.13	0.89	24.00	0.91	26.19
569	41.33	6.27	36.60	1.73	0.92	3.32	3.39	2.66	1.02	14.10	0.50	13.18
WG-73	42.40	5.07	37.07	1.70	1.05	3.35	3.18	2.16	0.84	20.10	0.63	13.53
WG-7	43.27	5.07	38.27	1.43	1.33	3.54	3.43	2.44	0.80	23.00	0.45	13.44
RG-464	31.43	5.17	28.50	1.33	1.10	3.19	3.13	2.50	0.75	20.80	0.52	11.05
IC-375107	36.93	5.07	32.23	1.60	1.27	3.30	3.41	2.75	0.79	24.20	0.50	15.24
543	34.10	5.27	32.30	1.23	1.27	3.14	3.10	2.51	0.82	23.33	0.45	11.21
WG-2	39.83	5.20	35.50	1.23	1.34	3.03	3.33	2.11	0.84	25.53	0.40	13.24
650	39.70	5.20	36.30	1.70	1.30	3.45	3.42	2.47	0.72	22.43	0.52	15.68
BRG-10	45.10	8.10	41.30	1.75	1.12	3.48	3.45	2.53	0.76	29.00	0.53	17.64
RAU-G5	40.17	6.13	35.33	1.73	1.06	3.28	3.06	2.96	0.96	15.43	0.65	14.82
IC-375119	52.07	7.63	47.63	1.77	1.11	2.92	3.20	2.52	1.01	22.23	0.53	13.69
G1	45.13	6.04	43.83	1.70	1.17	3.66	3.56	2.13	0.91	20.33	0.44	14.30
BRG-3	39.10	5.40	31.77	1.50	1.27	3.39	3.33	2.68	0.76	25.90	0.56	16.08
IC-290440	42.63	6.10	39.20	1.73	1.03	3.59	3.54	2.35	0.87	21.43	0.68	13.39
527	35.17	5.63	32.80	1.73	1.07	2.90	3.07	2.47	0.67	22.67	0.46	11.66
BRG-8	39.40	5.50	34.07	1.80	1.13	3.14	3.05	2.76	0.78	23.43	0.42	13.24
M-175	35.17	5.47	32.13	1.37	1.07	3.30	3.12	2.46	0.79	18.67	0.64	12.43
WG-7-1	35.97	5.33	25.20	1.43	1.19	2.93	2.86	2.42	0.83	17.10	0.59	12.18
Mean	40.48	5.73	36.49	1.58	1.17	3.32	3.3	2.51	0.83	23.13	0.53	14.64
C.V.	3.25	8.72	4.35	6.22	1.68	7.38	7.91	8.65	8.71	6.23	9.69	6.54
S.E.	0.76	0.29	0.92	0.06	0.01	0.14	0.15	0.13	0.04	0.83	0.03	0.55
C.D. 5%	2.16	0.82	2.60	0.16	0.03	0.40	0.43	0.36	0.12	2.36	0.08	1.57

at $P \leq 0.05$

PH = Plant height (cm), Le/P = Leaves per plant, LLe = Leaf length (cm), BrLe =Leaf width (cm), NTh = Neck thickness (cm), PDB = Bulb polar diameter (cm), EDB = Bulb equatorial diameter (cm), LC = Clove length (cm), WdC = Clove width (cm), C/B = Cloves per bulb, AWC = Clove average weight (g), Y/P = Yield per plant (g)

leaf length, yield per plant, cloves per bulb, average clove weight, and leaf width had high heritability. Genetic advancement was moderate for leaf length, plant height, and cloves per bulb (Table 2). Low genetic advance recorded for yield per plant, a number of leaves per plant, polar diameter of the bulb, clove length, leaf width, clove width, clove weight and equatorial bulb diameter. Higher bulb yield may be attributed to cumulative effects of neck thickness, plant height, cloves per bulb and average clove weight, all were found to be noble. The value of GCV is higher than PCV, indicates that there is little influence of environment on the expression of character. Hence, selection for improvement of such character will be rewarding. If the value of PCV is higher than GCV, means that apparent variation is due to genotype but also due to the influence of the environment. ECV is higher than GCV and PCV, it indicates that environment playing a significant role in the expression of such character. A close variation in all characters among the genotypes was reported by Singh et al. [16], Shrivastava et al. [17], and Raghuwanshi et al. [18]. Based on mean performance, genotypes exhibited wide variation for yield attributing characters and can be utilised by breeders for improvement of desired traits. In general, the phenotypic coefficient of variation was higher than its corresponding genotypic coefficient of variation. Determination of heritability and the genetic characters that compose heritability estimate is to compare the expected gains from selection based on alternative selection strategies. Average clove weight had the highest coefficient of variation at genotypic and phenotypic levels. significant observations were reported by Mehta and Patel [19] for clove weight and bulb yield per plant; Frasca et al. [20] for bulb weight; Narayan and Khan [21] for bulb yield per plot and bulb weight; Shri [22] for bulb yield and weight of 50 cloves; Agrawal and Tiwari [23] for clove weight and bulb yield; Singh and Chand [24] for average clove weight, bulb weight and bulb yield, and Haydar et al. [25] for bulb yield.

3.2 Correlation between Bulb Yield Attributing Characters

Plant height had significant, positive, correlations with leaves per plant; leaf length, bulb equatorial diameter, and clove width. Leaves per plant were significantly, and positively, correlated with leaf length, leaf width; average clove weight, clove width, and clove length. Leaf length was significantly, and positively, correlated with leaf width, polar and equatorial bulb diameters, and clove width. Leaf width was significantly, and positively, correlated with average clove weight, clove length, bulb polar diameter, and clove width. Neck thickness was significantly, and negatively, correlated with leaf width and clove width. Bulb polar diameter was significantly, and positively, correlated with bulb equatorial diameter, average clove weight and clove length. Equatorial bulb diameter was significantly, and positively, correlated with cloves per bulb. Clove length was significantly, and positively, correlated with average clove weight and clove width. Clove width was significantly, and positively, correlated with average clove weight. Cloves per bulb were significantly, and negatively, correlated with average clove weight. Average clove weight was significantly, and positively, correlated with yield per plant. If the value of r bears negative (-) sign, it indicates that the increase in the value of one character will lead to decrease in second character and *vice versa.* If it bears positive (+) signs, it means that an increase in one variable will result in an increase in the second character. If the value of genotypic correlation is higher than phenotypic correlation, it indicates there is a strong association between these two characters genetically, but the phenotypic value is lessened by the significant interaction of environment. Correlation coefficients are useful in determining bulb yield components which can be used for genetic improvement of yield. It always helps in ignorance of other independent variables affect and estimated from variance and co-variances. These findings have least closely related with Agrawal and Tiwari [26], Khar et al. [27], Khar et al. [28], Singh et al. [9], Patil et al.[29], Panse et al. [30], and Shree et al. [13].

3.3 Direct and Indirect Relationship between the Variables for Yield

Path coefficient analysis indicated plant height had the highest positive direct effect on bulb yield followed by clove length, bulb polar diameter, and leaves per plant. The result of direct analysis helps in measures the cause of association between two variables. It provides information about the direct and indirect effects of independent variables on dependent variables (yield). Path analysis helps in determining yield contributing characters and thus is useful in indirect selection of characters. Results agree with Patil et al. [29] for plant height and Singh et al. [24] for average clove weight. These characters had correlation coefficients similar to their direct effects on bulb yield per plant.

Highest negative, direct, the effect was for clove width, cloves per bulb, leaf width, and bulb equatorial diameter, and noble with Panse et al. [30] for bulb diameter. These characters exhibited significant correlation with bulb yield per plant. The role of these traits in the contribution towards bulb yield cannot be ignored because these characters are contributing directly towards the selection of character for yield improvement, the correlation mainly due to indirect effects of the character through another component trait, indirect selection through such trait will be live in yield improvement [31].

Table 2. Mean, range, coefficient of variation, heritability, genetic advance and genetic advance as % of mean indicating association for effective selection on bulb yield characters

Character	General mean	Range	Coefficient of variation			Heritability (h^2bs) %	Genetic advance	Genetic advance as % of mean
			GCV	PCV	ECV			
PH	40.48	31.43-52.07	12.30	12.72	3.25	93	12.71	31.39
Le/P	5.73	5.07-8.10	13.39	15.98	8.72	70	1.70	29.63
Lle	36.50	25.20-48.00	14.82	15.44	4.35	92	13.70	37.53
BrLe	1.59	1.23-1.80	9.84	11.64	6.22	71	0.35	21.95
NTh	1.17	0.91-1.37	9.21	12.67	8.71	53	0.15	17.66
PDB	3.32	2.81-3.93	7.73	10.69	7.38	52	0.49	14.77
EDB	3.30	2.86-3.65	4.31	9.01	7.91	23	0.18	5.45
LC	2.51	2.17-3.13	8.92	12.42	8.65	52	0.42	16.91
WdC	0.82	0.67-1.01	9.21	12.67	8.71	53	0.15	17.66
C/B	23.14	14.1-31.37	17.89	18.94	6.23	89	10.32	44.60
AWC	0.54	0.35-0.91	20.73	22.88	9.69	82	0.27	49.58
Y/P	14.64	11.05-26.19	20.34	21.37	6.54	91	7.48	51.13

at P≤0.05

[a]PH = Plant height (cm), Le/P = Leaves per plant, LLe = Leaf length(cm), BrLe = Leaf width (cm), NTh = Neck thickness(cm), PDB = Bulb polar diameter (cm), EDB = Bulb equatorial diameter (cm), LC = Clove length (cm), WdC = Clove width (cm), C/B = Cloves per bulb, AWC = Clove average weight(g), Y/P = Yield per plant(g)

Table 3. Estimates of genotypic and phenotypic correlation coefficients between the quantitave characters of garlic for bulb yield

Character		Le/P	LLe	BrLe	NTh	PDB	EDB	LC	WdC	C/B	AWC	Y/P
PH	G	0.47**	0.91**	0.41**	0.03	0.25	0.75**	-0.02	0.56**	0.26	0.14	0.46**
	P	0.4**	0.86**	0.37**	0.02	0.17	0.37**	0.03	0.43**	0.25	0.12	0.44**
Le/P	G		0.61**	0.57**	-0.11	0.21	0.16	0.33**	0.43**	-0.02	0.39**	0.5**
	P		0.52**	0.49**	-0.09	0.15	0.08	0.25	0.36**	0.02	0.35**	0.41**
LLe	G			0.46**	0.05	0.44**	0.85**	0.11	0.55**	0.28	0.28	0.59**
	P			0.41**	0.05	0.34**	0.39**	0.06	0.39**	0.25	0.22	0.55**
BrLe	G				-0.41**	0.39**	0.24	0.46**	0.3*	-0.15	0.34**	0.4**
	P				-0.33**	0.2	0.15	0.27	0.26	-0.1	0.28	0.34**
NTh	G					0	0.27	-0.13	-0.37**	0.55**	-0.19	0.36**
	P					0	0.16	-0.1	-0.26	0.52**	-0.18	0.35**
PDB	G						0.84**	0.47**	0.29	0.17	0.56**	0.62**
	P						0.3	0.23	0.11	0.08	0.31	0.47**
EDB	G							0.07	0.17	0.57**	0.08	0.82**
	P							0.02	0.17	0.4	0.1	0.44**
LC	G								0.29	-0.19	0.65**	0.56**
	P								0.19	-0.1	0.46**	0.38**
WdC	G									-0.19	0.39**	0.15
	P									-0.31**	0.3*	0.11
C/B	G										-0.33**	0.42**
	P										-0.26	0.4**
AWC	G											0.6**
	P											0.53**

at P≤0.05

P = Phenotypic, G = Genotypic, PH = Plant height (cm), Le/P = Leaves per plant, LLe = Leaf length(cm), BrLe = Leaf width (cm), NTh = Neck thickness(cm), PDB = Bulb polar diameter(cm), EDB = Bulb equatorial diameter (cm), LC = Clove length (cm), WdC = Clove width (cm), C/B = Cloves per bulb, AWC = Clove average weight(g), Y/P = Yield per plant(g)

Table 4. Estimates of direct and indirect effect of genotypic and phenotypic character selection for yield improvement of garlic. Direct selection can be made on traits for bulb yield enhancement

Character		PH	Le/P	LLe	BrLe	NTh	PDB	EDB	LC	WdC	C/B	AWC	Y/P
PH	G	**0.99**	0.47	0.90	0.41	0.03	0.24	0.74	-0.02	0.55	0.26	0.13	**0.46**
	P	**0.04**	0.02	0.04	0.02	0.00	0.01	0.02	0.00	0.02	0.01	0.01	**0.44**
Le/P	G	0.15	**0.32**	0.20	0.18	-0.03	0.07	0.05	0.11	0.14	-0.01	0.13	**0.50**
	P	0.02	**0.05**	0.02	0.02	0.00	0.01	0.00	0.01	0.02	0.00	0.02	**0.41**
LLe	G	0.07	0.05	**0.07**	0.03	0.00	0.03	0.06	0.01	0.04	0.02	0.02	**0.59**
	P	0.16	0.10	**0.19**	0.08	0.01	0.06	0.07	0.01	0.07	0.05	0.04	**0.55**
BrLe	G	-0.16	-0.23	-0.18	**-0.40**	0.16	-0.16	-0.09	-0.18	-0.12	0.06	-0.13	**0.40**
	P	0.06	0.08	0.07	**0.16**	-0.05	0.03	0.02	0.04	0.04	-0.02	0.05	**0.34**
NTh	G	0.01	-0.02	0.01	-0.08	**0.20**	0.00	0.06	-0.03	-0.08	0.11	-0.04	**0.36**
	P	0.01	-0.03	0.02	-0.11	**0.33**	0.00	0.05	-0.03	-0.09	0.17	-0.06	**0.35**
PDB	G	0.14	0.12	0.25	0.22	0.00	**0.56**	0.47	0.27	0.16	0.09	0.32	**0.62**
	P	0.03	0.02	0.05	0.03	0.00	**0.15**	0.05	0.03	0.02	0.01	0.05	**0.47**
EDB	G	-0.07	-0.02	-0.08	-0.02	-0.03	-0.08	**-0.10**	-0.01	-0.02	-0.05	-0.01	**0.82**
	P	0.04	0.01	0.04	0.01	0.02	0.03	**0.10**	0.00	0.02	0.04	0.01	**0.44**
LC	G	-0.11	0.19	0.06	0.28	-0.08	0.28	0.04	**0.59**	0.17	-0.11	0.39	**0.56**
	P	0.01	0.04	0.01	0.04	-0.02	0.03	0.00	**0.15**	0.03	-0.01	0.07	**0.38**
WdC	G	-0.53	-0.41	-0.52	-0.29	0.35	-0.27	-0.16	-0.28	**-0.95**	0.49	-0.37	**0.15**
	P	-0.03	-0.03	-0.03	-0.02	0.02	-0.01	-0.01	-0.01	**-0.07**	0.02	-0.02	**0.11**
C/B	G	-0.11	0.01	-0.12	0.07	-0.24	-0.07	-0.25	0.08	0.23	**-0.44**	0.14	**0.42**
	P	0.06	0.01	0.06	-0.02	0.13	0.02	0.10	-0.02	-0.08	**0.24**	-0.06	**0.40**
AWC	G	0.00	0.01	0.01	0.01	-0.01	0.02	0.00	0.02	0.01	-0.01	**0.03**	**0.60**
	P	0.05	0.16	0.10	0.13	-0.08	0.14	0.04	0.21	0.13	-0.12	**0.45**	**0.53**
Y/P	G	**0.99**	0.47	0.90	0.41	0.03	0.24	0.74	-0.02	0.55	0.26	0.13	**0.46**
	P	**0.04**	0.02	0.04	0.02	0.00	0.01	0.02	0.00	0.02	0.01	0.01	**0.44**

at $P \leq 0.05$.

P = Phenotypic, G = Genotypic, PH = Plant height (cm), Le/P = Leaves per plant, LLe = Leaf length(cm), BrLe = Leaf width (cm), NTh = Neck thickness(cm), PDB = Bulb polar diameter(cm), EDB = Bulb equatorial diameter (cm), LC = Clove length (cm), WdC = Clove width (cm), C/B = Cloves per bulb, AWC = Clove average weight(g), Y/P = Yield per plant(g). P = Phenotypic and G = Genotypic. Bold Numbers are indicating direct effect (negative and positive) on bulb yield

Positive, indirect, effects on bulb yield per plant occurred for plant height via leaf length, bulb equatorial diameter, clove width, leaves per plant, leaf width, cloves/plant and average clove weight. Indirect effects for a number of leaves per plant via leaf length, leaf width, plant height, clove width, average clove weight, and clove length were positive and lower magnitude. Leaf length exhibited indirect effects via plant height, bulb equatorial diameter, leaves per plant, clove width, leaf width and clove polar diameter. Leaf breadth shows indirect, positive, effects via neck thickness. Neck thickness exhibited positive, indirect effects via cloves per bulb. Clove polar diameter exhibited positive, indirect, effects in all traits except leaves per plant, neck thickness, clove width which exhibited low magnitudes. Positive, indirect, effects were the length of cloves via average clove weight, bulb polar diameter, leaf width breadth and clove width. Clove width exhibited positive, indirect, effects for coves per bulb and neck thickness. Cloves per bulb exhibited positive, indirect, effects for clove width and average clove weight. Average clove weight exhibited positive, indirect, effects for clove length, bulb polar diameter, clove width and leaves per plant. These findings are closely correlated with Shrivastava et al. [17].

Higher magnitudes of negative, indirect, effects occurred for leaf width via leaves per plant, clove length, plant height, bulb polar diameter, average clove weight and clove width. Indirect effects for equatorial bulb diameter occurred with negative, indirect, effects via leaf length, bulb polar diameter, plant height, cloves per bulb, neck thickness and leaf width. Clove width had the highest, negative, indirect effect via plant height, leaf length, leaves per plant, average clove weight, leaf width, clove length, and bulb polar diameter. Cloves per bulb had the highest negative, indirect, effect via bulb equatorial diameter, neck thickness, leaf length and plant height. These findings are noble with Singh et al. [32] and Bhatt et al. [33].

4. CONCLUSION AND FURTHER USE FOR GARLIC YIELD IMPROVEMENT

All combination of traits should be considered while selecting for high yielding genotypes. Plant height, leaf length, clove width and average clove

weight can be used for direct selection for high yield in garlic because these characters exhibited high GCV, PCV, heritability and genetic advance as percent of mean and exerted a direct effect on yield. Genotype 644 found highest yielder might be considering for commercial cultivation.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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