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Genetic Variability and Character Association for Bulb Yield and Yield Related Traits in Garlic in Ethiopia

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Abstract

Garlic (*Allium sativum*) has for centuries been valued by humans for food, culinary and medicinal purposes world over. The objective of this study was to investigate genetic variability among garlic accessions for yield, yield related and phenology traits in Ethiopia. A field study was conducted in the DebreZeit Agricultural Research Center during 2012, using 49 garlic accessions from the highlands of North Shewa, East and West Arsi, Arsi, Bale and Sidama zones, which are among the major garlic producing areas in Ethiopia. Treatments included the 49 accessions arranged in a 7*7 simple Lattice design, with two replications. Accession were highly significant ($p < 0.01$) for days to maturity, leaf number per plant, neck diameter, yield per plant, biological yield per plant, dry weight above ground, bulb dry weight, dry weight underground, clove number per bulb, and clove weight per bulb. Heritability estimates ranged from 82.48% for clove number, to 6.46% harvest index. High heritability, combined with high genetic advance (as per cent of mean) observed for mean clove number, yield per plant, biological yield per plant and clove weight per plant showed that these characters were controlled by additive gene effects; and phenotypic selection for these characters would likely be effective in variety selection and development. Bulb yield per plant had positive and highly significant genotypic and phenotypic correlations, with all characters except plant height and harvest index. Path analysis at phenotypic level revealed that biological yield and bulb dry weight contributed major positive direct effects to bulb yield per plant. These traits showed positive and highly significant genotypic correlations with bulb yield except harvest index.

Keywords: *Allium sativum*; Genetic variability; Heritability

Introduction

Garlic (*Allium sativum* L. *var. ascalonicum* Baker, 2n=16) is a widely cultivated in Ethiopia and preferred by most Ethiopians for its strong pungent culinary value. Garlic and its close relatives, onion *(Allium cepa* L.), leek (*A. porrum*) and chives (*A. schoenoprasum*) are common vegetable crops throughout the world, which have been cultivated since 3000 B.C. According to Novak et al. and Brewster, there are more than 500 species within the genus, originated in central Asia. Ethiopia has been undertaking research on garlic since mid-1980s with the main objectives of collecting, characterizing and evaluating accessions from major growing regions of the country; even though not exhaustively from all highland areas [1]. As a result, three garlic varieties were obtained and released for being better yielders than the unimproved cultivars. The present study focuses on morphological variability of newly collected garlic accessions not addressed in the past studies of variety developments. The objective of this study was to assess the extent of genetic variability for bulb yield and yield related traits of garlic and estimate heritability in broad sense and expected genetic advance due to selection in garlic in the Ethiopian highlands.

Materials and methods

Experimental site

This study was conducted at Debre Zeit, in Ethiopia, located at 8°7°N and 39°E, at an altitude of 1990 metres above sea level. The annual rainfall at the site reaches 866 m, with the long rainy season extending from June to September, and accounting for 84% of the precipitation. The mean annual maximum and minimum temperature ranges are 26 and 14 °C, respectively (Lemma and Derresa, 2009). The site soil was a Vertisol.

Experimental materials

A total of 49 garlic accessions collected earlier from north Shewa, east and west Arsi, Arsi, Baleand Sidama zones of Ethiopia in 2011, and maintained at Debre Zeit Agricultural Research Centre, were used for this study.

Experimental layout and management

Treatments included the 49 accessions laid out in a 7x7 simple lattice design, with two replications. Healthy and normal cloves of each accession were selected and planted on prepared plots of 2 m by 2.4 m. Each plot consisted of four rows, with 20 plants per row, and a total of 80 plants per plot. Plants pacing was 30 cm and 10 cm. Alleys of 1.5 cm each were left between plots. The middle two rows were used for data collection. Field agronomic practices used were as recommended for the crop.

Data collection and analysis

Data collection included determination of days to seedling emergence and to maturity, plant height, leaf length and width, number of leaves per plant, neck diameter, bulb yield per plant, biological

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yield per plant, above and underground dry weight, bulb dry weight, clove number per bulb, clove weight per bulb and harvest index (%). These were recorded from eight randomly sampled plants in the two central rows of each plot, using the description of International Plant Genetic Resources Institute.

The data collected were subjected to analysis of variance (ANOVA) for simple lattice design, using Proc Lattice and proc GLM procedures of SAS version 9.2 [2]. Differences between significant treatment means were compared using least significant difference (LSD) at 1 and 5% probability levels. Correlation coefficients were analysed to estimate the nature and degree of association of component characters with yield to identify characters that played decisive roles in influencing yield.

Results

There were highly significant ($p<0.01$) effects of garlic accessions on traits including leaf length, leaf width and days to emergence, suggesting the existence of sufficient genetic variability for use in garlic varietal improvement. However, there were no significant ($p>0.05$) effects for harvest index and plant height.

There were highly significant variations among accessions in skin colour, bulb diameter, and weight of cloves, number of bulbils, bulbil weight, plant vigour, leaf diameter (leaf width) and leaf number in garlic genotypes.

Belowground dry weight and biological yield

Dry weight (DW) of underground parts and biological yield per plant exhibited a wide range of variation among the accessions (Table 1). The maximum and minimum DW of bulb and biological yield per plant were121.4 and 52.63 g , and 71.56 and 28 g, respectively. Higher heritability (h^2) was recorded for days to maturity (82.48%), average clove number (80.08%), yield per plant (58.96%), neck diameter (56.57%), and biological yield per plant (55.26%). Wider ranges were observed for yield per plant (16.16-48.91), biological yield per plant (28-71.57), average clove number (7.5-24.1), and dry weight underground (52.63-121.36).

Variables	MSR	MSB	MSG	MSE	CV%
Date to emergence	24.50**	1.69ns	2.73*	1.64	9.91
Days to maturity	9.81ns	11.75ns	99.55**	9.89	2.59
Plant height	17.49ns	17.65ns	13.05ns	8.13	5.58
Leaf length	7.55ns	10.38*	8.23*	4.29	5.64
Leaf width	0.02ns	0.01ns	0.012*	0.01	5.07
Leaf number per plant	4.29**	0.98ns	1.35**	0.55	6.08
Neck diameter	0.06ns	1.29ns	2.67**	0.61	9.64
Yield per plant	34.68ns	29.05ns	88.93**	23.43	15.42
Biological yield per plant	94.43ns	101.54ns	227.45**	64.29	18.80
Dry weight above ground	0.003ns	0.71ns	1.58**	0.51	25.12
Bulb dry weight	1.70ns	4.17ns	7.45**	2.53	16.04
Dry weight under ground	121.23ns	277.17ns	478.34**	162.66	16.09
Clove number per bulb	6.48ns	6.75ns	40.62**	4.46	14.56
Clove weight per Bulb	3.13ns	34.21ns	59.33**	15.26	15.52
Harvest Index (%)	50.86ns	194.87ns	110.54ns	101.76	13.43

*, ** significant at 0.05 and 0.01 probability level, respectively; ns

= non-significant; MSR=Mean square of replication; MSB =Mean square of block; MSG =mean square of genotype; MSE =Mean square of error; CV = Coefficient of Variation

Table 1: Analysis of variance for 15 traits of garlic the accessions grown at debre zeit research station.

Days to emergence and maturity

Significant variation in days to emergence and maturity were recorded among the accessions. Generally, the accessions required 97 to 130 days from planting to maturity. The early maturing accession (97 days) was G-19/03 and the late maturing (122.5 -131 days) were G-28/03, G-30/03, G-31/03, G-32/03, G-33/03, G-37/03, G-59/03, G-69/03, G-74/03 and G-77/03.

Plant height and leaf length

A wide variation was observed in plant height and leaf length among the accessions. Genotypes G-50/03 and G-7/2003 had the shortest plant height (43.65 cm), fewest number of leaves per plant with shortest leaf (32.3 cm) and the narrowest neck diameter (5.9 cm) respectively but G-32/2003 had the widest neck diameter (11.05 cm and largest number of leaves per plant (14.85) and widest leaf (1.65 cm); whereas the narrowest (1.35 cm) leaf was observed in G-21/2003. A wide range of variation also occurred in biological yield among the accessions. The maximum biological yield was recorded in accession G-32/03 (71.550 g) whereas G-50/03 had the lowest (28.0 g) with the mean 42.65. Likewise, yield per plant and dry weight of the underground parts were extremely variable; the smallest was observed in G-15/03 (16.16 g) for yield per plant and largest in G-30/2003 (48.91 g); while the largest was observed in G- 32/03 (121.36 g) for dry weight underground and smallest was recorded for G-41/2003 (52.63 g). Similarly, for harvest index, average clove weight per plant, average cloves number and bulb dry weight per plant also exhibited wide variations.

The lowest harvest index (58.44%) was recorded in G-15/03; while the highest was observed in (90.85%) in G- 50/03. This indicates G-50/03 was 32.41% more efficient than G-15/03 in converting photosynthates to economical product. G-29/03 had the smallest cloves (17.5 g) but G-32/03had the biggest cloves (42.70 g) among the accessions. The average number of cloves was very low in G-18/03 (7.5 cloves); whereas G-34/03 yielded 24.1 cloves. The dry weight of bulbs per plant between the accession that yielded the smallest G-41/2003 (6.6 g), and the highest was G-32/2003 (15.15 g), more than double.

Estimation of genotypic and phenotypic variance

A large amount of variability was noticed with respect to all the characters under the study. Among the traits, high genotypic coefficient of variation (31.35%) was recorded for average cloves number per plant; followed by dry weight above ground (24.56%), biological yield per plant (21.77%), yield per plant (18.92%), bulb dry weight per plant (15.24%), dry weight underground parts (15.21%) and average clove weight per plant (17.89%), neck diameter (12.23%) and days to emergence (6.47%), and days to maturity (5.86%).

The estimated genotypic coefficient of variation ranged from (31.35%) for average clove number to (0.00%) for leaf width per plant and phenotypic coefficient of variation also varied from (37.54%) for dry weight above ground to (6.45%) for days to maturity.

Estimation of heritability in broad sense

Moderate heritability was observed for bulb dry weight per plant (42.72%), dry weight above ground (42.61), dry weight underground (42.27%), leaf number per plant (36.11%), plant height (28.5%), leaf length per plant (25.61%), date to emergence (24.65%) and leaf width per plant (21.9%) but low heritability was recorded for harvest index (6.46%).

Estimation of expected genetic advance

High genetic advance was attained for dry weight underground (16.15), biological yield per plant (14.28), and days to maturation (13.27). Intermediate values were obtained for yield per plant (9.35), average clove number (8.38), average clove weight (6.59), days to emergence (6.62%), leaf number per plant (6.31%), and plant height (4.31%). The lowest values were recorded for plant height, bulb dry weight, neck diameter, harvest index, leaf length per plant, dry weight above ground, date to emergence, and leaf number per plant and leaf width per plant.

In this study, traits which had higher estimates of heritability and genetic advance from the other yield contributing traits were dry weight of underground parts, days to maturity, biological yield per plant and clove weight per plant, suggested as traits for indirect selection. Yield per plant and clove number per bulb are suggested for direct selection.

Path coefficient analysis

Path coefficient analysis appeared to provide a clue onto the contribution of various components of yield to overall bulb yields in the genotypic and phenotypic correlation. It provided an effective way of finding out direct and indirect sources of correlation. Direct and indirect effects of these components were determined on bulb yield. Path analysis at phenotypic level revealed that biological yield (1.068) and bulb dry weight (0.913) contributed major positive direct effects to bulb yield per plant. These traits showed positive and highly significant genotypic correlations with bulb yield, except harvest index. The other characters that exerted direct positive effects included harvest index; followed by dry weight above ground per plant, leaf length, days to maturity, average clove number, plant height, and neck diameter. As a result, these characters could be considered as major components for selection in a breeding programme for higher bulb yield. Earlier studies also indicated positive direct effects of plant height, number of splitted bulbs per plant and bulb diameter on bulb yield; suggesting that direct selection for bulb yield through these traits would be effective [3]. Singh reported a positive direct effect of harvest index and plant height on bulb yield of garlic and negative direct effects were shown on bulb yield by dry weight underground, leaf width, leaf number, average clove weight, and days to emergence. These negative direct effects were counter balanced by the positive indirect influences through plant height, leaf length, neck diameter, days to maturity, biological yield per plant, dry weight above ground, bulb dry weight, bulb dry weight underground, average clove number and bulb diameter. These traits, except plant height, had positive and highly significant phenotypic correlations with bulb yield. Plant height revealed a direct positive effect on bulb yield, but it had a non-significant correlation with bulb yield. Leaf length exhibited a positive direct effect on bulb yield and affected indirectly negatively *via* days to maturity, days to emergence, average clove number and harvest index.

Direct and indirect effects

Biological yield had maximum positive direct effect on bulb yield per plant followed by bulb dry weight, harvest index, days to maturity, leaf length, and dry weight above ground, plant height and average clove number. Biological yield showed favorable indirect effect on bulb yield through bulb diameter, dry weight above ground, bulb dry weight, average clove number, and average clove weight. The positive indirect effects nullify the negative indirect effects on bulb yield per plant *via* plant height, leaf length, neck diameter, days to emergence and days to maturity. Besides its positive and highly significant correlation with bulb yield, bulb dry weight showed direct positive effect on bulb yield per plant. Positive indirect effect on bulb yield per plant exerted by bulb dry weight was through dry weight underground, average clove number and average clove weight per bulb; whereas the negative indirect effect of bulb dry weight on bulb yield was exerted *via* plant height, leaf length, leaf width, leaf number, neck diameter, days to emergence, days to maturity, and dry weight above and ground parts. Days to maturity had positive and highly significant correlation with bulb yield per plant; besides it exerted maximum positive direct effect on bulb yield per plant. Its negative indirect effect on bulb yield per plant was through leaf width per plant, leaf number per plant, neck diameter, and harvest index. Its positive indirect effect exerted on bulb yield per plant was *via* plant height, leaf length, bulb diameter, dry weight above ground, bulb dry weight, dry weight underground, average clove number and average clove weight per plant. The negative indirect effect of this trait exerted to bulb yield was *via* leaf width, leaf number, and neck diameter, biological yield per plant, bulb dry weight, and dry weight above ground, dry weight underground and average clove weight. Although, dry weight of above ground parts positively and highly significant correlates with bulb yield per plant, it had minimum positive direct effect on bulb yield per plant. Positive indirect effects of this trait affected bulb yield per plant *via* plant height, bulb dry weight, and dry weight underground parts, average clove number and average clove weight. The indirect negative effect of this trait on bulb yield per plant was exerted through leaf length per plant, leaf width per plant, leaf number per plant, neck diameter, days indicates that harvest index might serve as indices for identifying genotypes with higher yield [5-8]. Thus, it can be inferred from this study that varieties having the potential of high production are of no use if they do not have the potential of converting large portion of biological yield into economic (bulb) yield. Therefore, it is of vital importance to give due attention to harvest index while selecting varieties for commercial cultivation as improving harvest index can substantially increase garlic yield. Biological yield per plant showed positive and highly significant phenotypic correlation with all characters except with days to emergence and plant height. In line with this study reported that plant height had highly significant positive correlation with number of leaves/plant, days to maturity, total yield, and highly significant negative correlation with bulb ratio in onion. As well it showed highly and positively significant correlation at phenotypic level with all traits except with harvest index. In harmony with this study, it was reported that number of leaves/plant had highly significant positive correlations with each of plant fresh weight and total yield in onion. Plant height, neck diameter, harvest index, leaf length, days to germination, leaf number per plant, dry weight above ground, leaf width per plant had low genetic advance and thus improvement through selection for these traits is not possible which might be due to non-additive gene action. This is in agreement with the finding. In line with the present study Marey et al. reported that plant dry weight showed a significant positive correlation with each of marketable yield/fed., and number of complete rings/bulb.

Conclusion

In this study, those characters with significant and positive correlation with bulb yield and positive direct effect will be considered for the utilization of the accessions for selection and variety development efforts. According to this study, it can be recommended that traits such as biological yield per plant and bulb dry weight that showed positive direct effect on bulb yield per plant at genotypic level could be good selection criteria to improve bulb yield in garlic through breeding/selection as showed sufficient genetic variability.

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