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VARIABILITY OF AGRONOMIC AND QUALITY CHARACTERISTICS OF GARLIC (*Allium sativum* L.) ECOTYPES

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SUMMARY

Garlic (*Allium sativum* L.) has been recognized for all over the world as a valuable spice for food as well as for its medicinal value. In order to identify large size bulbs having large clove diameter and high allicin content, 40 diverse genotypes of garlic genotypes were tested at Vegetable Research Farm and Biochemistry Laboratory, Department of Vegetable Science, Punjab Agricultural University, Ludhiana, during 2012-13 so that the suitable genotype should be identified for cultivation in Punjab state. The observations were recorded for ten agronomic traits and 6 quality parameters. Analysis of variance showed significant difference among all the genotypes for all the characters under study. For all the characters studied, phenotypic coefficients of variability were higher in magnitude than genotypic coefficients of variability. Bulb weight per plant, bulbil size, number of bulbils per umbel, clove weight and total sugars recorded high heritability. High heritability coupled with moderate genetic gain was expressed in numbers of clove per bulb, leaf width, alcohol insoluble solids and allicin content. The genotypes CSRG-1143 and CSRG-1153 have high bulb weight, high bulb and clove diameter, average number of cloves/bulb and moderate allicin content i.e. it can be released as a variety after multi-location testing. The line CSRG-1149 has highest allicin, less number of bulbils per umbel and small bulbil size i.e. it has potential of flowering and seed production under high day length conditions.

Key words: Variability, genetic divergence, allicin, quality

Key findings: The lines CSRG-1143 and CSRG-1153 can be used by breeders for improvement in agronomic traits of garlic after clonal selections.

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INTRODUCTION

Garlic (*Allium sativum* L.) is one of the most important bulb vegetable crops which have been used throughout recorded history for culinary, medicinal use and health benefits. (Velisek *et al.*, 1997). At the national level, it is the second most important cultivated bulb crop after onion in area and production (Shankar *et al.,* 1997). In Asia, people use fresh leaves of garlic as salad and pickle is also prepared from garlic cloves (Pandey and Singh, 1987). Garlic has higher nutritive value than other bulb crops (Pandey, 1989) and has good export potential as fresh bulb as well as in the dehydrated form (Gupta and Singh, 1998). Garlic has several medicinal values such as antibacterial, antifungal, antiviral, antiprotozol, antioxidant and anticancer properties (Harris *et al.,* 2001). It has benefits in lowering total plasma cholesterol, reducing blood pressure and decreasing platelet aggregation (Mayeux *et al.,* 1998; Sterling and Eagling, 2001). Besides, it is good for heart, immune system and also acts as anti-diabetic and anti-arthritis. Allicin (diallylthiosulfinate),

a volatile compound responsible for the pungent smell of garlic, is a chemically unstable and highly reactive molecule. Most of the medicinal effects of garlic are attributed to a sulphur compound known as allicin (Mayeux *et al*., 1998).

Garlic reproduces almost exclusively by means of underground cloves or vegetative top sets in the inflorescence and is mostly sterile. Since garlic has been propagated asexually for many generations, an accumulation of chromosome aberrations such as aneuploidy and translocations and/or inversions could also significantly reduce the incidence of balanced gametes. Therefore variation in garlic occurs only through random or induced mutation (Burba, 1993) and/or somaclonal variation (Novak, 1990) and new cultivars are bred by clonal selection, induced mutations, somaclonal variation or genetic engineering (Jones and Mann, 1963; Rubatzky and Yamaguchi, 1997; Robinson, 2007). The lack of sexuality in garlic limits the increase of variability that is useful for breeding for economically important traits, such as tolerance to biotic and abiotic stress, earliness, yield and quality (Kamenetsky, 2007).

A series of different ecotypes have been established over time in various areas of cultivation. Considerable morphological and biochemical variations between and within ecotypes are displayed (Bradley *et al.,* 1996; Avato *et al.,* 1998). These differences were described with the objective of selecting the best quality of active substance (Avato *et al*., 1998). To meet the domestic requirement and fulfill the export demand, selection of suitable variety for growing under different agroclimatic condition is necessary. As this crop is propagated vegetatively, variation in garlic occurs only through random or induced mutation and/or somaclonal variation and new cultivars are bred by clonal selection, induced mutations, somaclonal variation or genetic engineering. Very scanty work has been done on the association between different traits, which are prerequisites for executing a selection program. With a view to develop large bulb and clove size garlic varieties with high yield and allicin content, the Punjab Agricultural University, Ludhiana collected germplasm across the country and conducted field experiment to assess the potential of genetic resources to identify cloves having high bulb yield with large sized cloves, high allicin content, and other desirable traits.

MATERIALS AND METHODS

The experimental material consisted of 40 genotypes (Table 1) of garlic selected from a diverse collection of germplasm, maintained at the Vegetable Research Farm of Department of Vegetable Science, Punjab Agricultural University, Ludhiana. The material was grown in RCBD with 3 replications. Planting of cloves was done at a spacing of 15 cm x 7.5 cm in first fortnight of October 2012. The recommended agro-practices were followed to ensure a healthy crop growth and development. The observations were recorded at maximum growth stage and after harvesting on randomly selected 10 plants in each replications for all the characters viz., leaf length (cm), leaf width (cm), number of leaves per plant, scape length (cm), bulb diameter (mm), number of cloves/bulb, clove weight (g), bulb weight (g), number of bulbils/umbel, bulbil size, dry matter (%), ash content (%), crude protein (%) was estimated by Kjeldahl method of nitrogen estimation (McKenzie and Wallace, 1954), total soluble sugars (%) was estimated using the method given by Dubios *et al.* (1956), alcohol insoluble insolids (%) (Woodward, 1972) and allicin content (%) estimated by a method adopted from Jafarian *et al.* (2003). The data was statistically analyzed for variance using the standard procedure by Gomez and Gomez (1984). The genotypic and phenotypic coefficient of variations was analyzed as suggested by Burton and De vane (1958). Heritability in broad sense and expected genetic advance as percentage of mean was calculated using the method suggested by Johnson *et al.* (1955). Analysis of variance of all the parameters was performed using CPCS-1 software and the means were separated by Fisher's least significant difference at 5% level of significance.

RESULTS AND DISCUSSION

All the characters showed significant variances, indicating that there was sufficient diversity among the germplasm.

Table 1. List of garlic genotypes studied along with their sources.

Genotype	Source	Genotype	Source
BG109	IIVR,Varanasi	CG-115	AINRPOG
BG110	IIVR,Varanasi	CG-118	AINRPOG
BG111	IIVR,Varanasi	CG-119	AINRPOG
G-1	Delhi	BSRG-1123	AINRPOG
G-50	Haryana	BSRG-1130	AINRPOG
G-282	Tamil Nadu	BSRG-1133	AINRPOG
G-323	Tamil Nadu	BSRG-1136	AINRPOG
Darl-52	Uttaranchal	ASRG-1101	AINRPOG
PG-18	Punjab	ASRG-1104	AINRPOG
PG-19	Punjab	ASRG-1107	AINRPOG
PG-36	Punjab	ASRG-1109	AINRPOG
PG-37	Punjab	ASRG-1112	AINRPOG
PG-38	Punjab	ASRG-1115	AINRPOG
PG-39	Punjab	ASRG-1117	AINRPOG
PG-40	Punjab	CSRG-1138	AINRPOG
PG-42	Punjab	CSRG-1140	AINRPOG
PG-43	Punjab	CSRG-1143	AINRPOG
CG-112	AINRPOG	CSRG-1149	AINRPOG
CG-113	AINRPOG	CSRG-1153	AINRPOG
CG-114	AINRPOG	CSRG-1154	AINRPOG

AINRPOG: All India Network Research Program on Onion and Garlic

Bulb weight per plant is the most important yield contributing component and it showed much variability in garlic genotypes used in this study. Bulb weight of genotype ASRG-1117 (33.3 g) was highest among the genotypes followed by CSRG-1153 (30.8 g) and CSRG-1138 (29.9 g). The range and mean for bulb weight was recorded as 9.0-33.3g and 18.1g, respectively. Significant variation for bulb weight per plant in garlic was also reported by Gvozdanovic *et al* (2002), Godhani and Singh (2003) and Zahedi (2007). The number of cloves per bulb ranged from 28.7-10.3 and mean was 20.0 and genotype CSRG-1154 produced highest number of cloves per bulb 28.7 followed by CSRG-1153 (27.3).The findings are consistent with the observations of Gvozdanovic *et al* (2002), Godhani and Singh (2003), Zahedi (2007) and Sayed *et al.* (2007). Other important trait weight of clove CSRG-1138 and PG-37 were recorded the maximum 1.37g. The range and mean for clove weight was 0.48-1.37g and 0.84g respectively, which are consistent with finding of Mehta and Patel (1985) and Gvozdanovic *et al.* (2002).

The allicin content is the most important nutritional component and it showed much variability in garlic genotypes used in this study. Allicin content of genotype CSRG-1149 (1.2%) was highest among all the genotypes, followed

by CSRG-1154 (0.9 %), BSRG-1123 (0.9%) with the range and mean 0.3-1.2% and 0.7% respectively. The range and mean for crude protein was 10.7-18.6% and 14.4% respectively. Such wide variation among clonal selections could be utilized by plant breeders for the improvement of desired traits.

The range of mean values based on phenotype expression could represent only an approximate estimate of the variation or magnitude of divergence present among different genotypes. The estimates of variability i.e. coefficient of variability, genotypic and phenotypic coefficients of variation, heritability and genetic advance percentage of the mean (genetic gain) presented in Table 2 were calculated for various characters in garlic. The observed variation in the characters studied among all the genotypes were due to effect of genotype and environment. However, environmental variation is not fixable. For determining the magnitude of genotypic and phenotypic variability, the genotypic and phenotypic coefficient of variation was calculated. Coefficients of variation varied in magnitude from character to character, either low, moderate or high, indicating considerable diversity in the germplasm studied. Phenotypic coefficients of variation were moderate for bulb weight (34.9%), clove weight (31.2%) and allicin content (19.5%). Godhani and Singh (2003) reported high phenotypic coefficient of variation for bulb weight, while moderate genotypic and phenotypic coefficients of variation for plant height and number of leaves per plant. Kohli and Prabhal (2000) reported for variation number of cloves per bulb, clove diameter and clove weight. In the experimental material, genotypic variability for all the characters under study ranged from 10.1 to 54.8%. Moderate expression of genotypic coefficients of variation was observed for bulb weight (34.3%), clove weight (29.2%), alcohol insoluble solids (26.4%), number of cloves (23.1%), bulb diameter (19.7%) and allicin content (19.4%). Godhani and Singh (2003) reported high genotypic coefficient of variation in bulb weight while moderate genotypic coefficients of variation for plant height and number of leaves per plant. For number of leaves per plant and plant height, low genotypic coefficient of variation was reported by Vijay (1990) and Mehta and Patel (1985). There were narrow differences between phenotypic and genotypic coefficient of variation in all the characters studied, indicating low environmental influence in expression of these characters, which implies that phenotypic variability is a reliable measure of genotypic variability. Therefore, selection for improvement of all traits is possible and effective on the phenotypic basis.

Selection is always favored when a major proportion of a large amount of phenotypic variability is due to heritable variation. Heritability is a measure of genetic relationship between parent and progeny and has been widely used in determining the degree to which a character may be transmitted from parents to offspring. Estimation of heritability in broad sense gives the extent of heritable component of variation. Knowledge of degree of heritability for the character permits a rational choice of breeding methods to be followed for its improvement and helps to estimate the genetic gains from selection. The heritability for all traits estimates ranged from 65.6 to 98.3. Very high heritability estimates were obtained for allicin content (98.3%), bulb weight (97.0%), bulb diameter (96.2%) and leaf width (90.4%), while moderate heritability estimates were obtained for crude protein (67.3%) and leaf length (65.6%). High heritability was also reported by Kohli and Prabhal (2000) and Kohli and Frageria (1992) for number of bulbils per plant and bulb diameter in garlic. Selection for a particular trait is made on the basis of phenotype, which is produced by the joint action of genotype and environment. Therefore, the phenotypic superiority of selected plants or families over the original population is not solely due to their genotypic superiority. It may be due to favorable environmental conditions, so only heritability estimates are not reliable. Genetic advance in such cases gives a good idea for actual position (Johnson *et al.,* 1955) as it provides information about improvement in the mean genotypic value of the selected families over base population. A high heritability coupled with high genetic advance gives effective criteria for selection. Genetic gain is the change achieved by artificial selection in a specific trait and is influenced by selection intensity, parental variation, and heritability.

Table 2. Coefficient of variation, heritability, genetic advance, genetic gain, range and general mean for different traits in garlic.

Character	Coefficient of variance	Phenotypic coefficient of variation (%)	Genotypic coefficient of variation (%)	Heritability (%)	Genetic advance (%)	Genetic gain (%)	Range	Mean ± SE(d)
Number of leaf	5.2	14.2	13.2	86.8	2.2	25.4	7.0-12.3	8.5
Number of clove	8.4	24.5	23.1	88.3	8.9	44.6	10.3-28.7	20.0
Bulbil diameter	3.9	20.1	19.7	96.2	1.3	39.8	1.8-4.5	3.3
Bulbil size	7.0	55.2	54.8	96.1	0.4	86.9	0.1-0.9	0.4
Number of bulbils /umbel	10.2	49.2	48.1	95.7	4.5	76.9	1.3-9.7	4.6
Leaf length	2.9	13.7	13.4	65.6	9.7	27.0	20.4-42.9	35.8
Clove weight	11.1	31.2	29.2	87.5	0.5	56.3	0.5-1.4	0.8
Leaf width	4.7	14.9	14.2	90.4	0.5	27.8	1.3-2.5	1.8
Scape length	3.7	16.2	15.8	94.7	12.9	31.6	29.4-53.5	40.8
Bulb weight	6.1	34.8	34.3	96.9	12.6	69.6	9.1-33.3	18.1
Dry matter	3.2	10.6	10.1	91.0	7.0	19.8	28.0-45.1	35.2
Ash content	11.9	26.6	23.8	80.0	0.2	43.9	0.3-0.7	0.5
Alcohol insoluble solids	4.3	26.7	26.4	97.4	2.8	53.6	20.0-55.3	38.7
Total sugars	2.1	28.9	28.9	97.1	1.1	79.7	0.3-2.5	1.1
Crude protein	9.0	15.7	12.9	67.3	3.1	21.8	10.7-18.6	14.4
Allicin content	0.8	19.5	19.5	98.3	0.3	40.1	0.3-1.2	0.7

Table 3. Mean performance of different line for different traits.

Genotype	Leaf Length (cm)	Leaf breadth (cm)	Scape length (cm)	Number of Leaves per plant	Bulb diameter (cm)	Number of Clove	Clove weight (g)	Bulb weight (g)	Number of Bulbil/ Umbel	Bulbil Size (mm)	Dry matter (%)	Ash content (DW %)	Alcohol insoluble solids (DW %)	Total sugars (DW %)	Crude protein (DW %)	Allicin content (FW %)
BG-109	20.4	1.5	35.7	8.0	3.7	28.0	0.7	20.6	9.7	0.2	38.8	0.4	42.0	0.6	15.4	0.7
BG-110	28.9	1.5	37.9	10.0	2.6	15.7	0.6	9.1	3.7	0.2	33.3	0.5	47.3	0.8	13.6	0.7
BG-111	29.2	1.6	36.2	8.0	3.1	14.7	0.6	9.3	2.0	0.4	37.5	0.3	33.3	0.9	10.7	0.3
G-1	35.5	1.7	41.9	8.3	2.7	19.7	0.6	20.5	1.7	0.2	45.1	0.5	49.3	0.7	16.2	0.6
G-50	40.4	2.0	39.0	9.7	2.5	17.3	0.5	18.7	1.7	0.2	36.1	0.4	31.3	1.3	12.5	0.7
G-282	35.8	1.8	30.2	7.3	3.4	20.7	1.0	11.0	4.7	0.4	41.1	0.4	46.7	1.3	13.5	0.7
G-323	34.4	1.5	33.7	7.3	4.0	20.3	1.2	24.2	4.0	0.2	33.1	0.6	39.3	0.9	15.2	0.5
Darl-52	35.3	1.6	41.3	9.3	3.4	21.3	0.7	18.0	1.3	0.5	34.4	0.3	52.7	1.2	15.3	0.8
PG-18	37.3	2.2	36.0	8.0	3.5	26.3	0.7	19.5	5.0	0.6	39.0	0.7	42.0	1.4	12.3	0.7
PG-19	41.5	1.7	35.8	8.3	3.9	18.0	0.7	12.9	2.0	0.2	32.3	0.5	47.3	0.4	11.8	0.7
PG-36	37.9	1.8	39.0	10.3	3.8	20.7	0.9	19.6	9.3	0.4	35.8	0.4	37.3	0.4	12.8	0.7
PG-37	35.3	1.3	34.7	9.0	3.5	11.7	1.4	17.4	3.3	0.6	34.4	0.3	20.0	0.8	14.3	0.6
PG-38	42.9	1.5	31.7	7.3	2.1	10.3	1.1	12.3	7.7	0.1	32.5	0.4	21.3	0.5	12.6	0.5
PG-39	34.9	1.6	39.7	8.0	1.8	10.7	0.6	9.7	5.7	0.4	32.3	0.3	29.3	0.6	12.0	0.6
PG-40	41.6	1.5	29.4	8.0	3.6	19.0	1.3	20.6	7.0	0.4	31.7	0.6	31.3	0.9	14.4	0.8
PG-42	36.3	1.4	31.3	8.0	2.7	14.3	0.8	11.8	3.3	0.2	38.2	0.4	26.7	0.9	17.3	0.7
PG-43	35.7	1.6	34.1	9.0	2.6	25.3	0.6	16.1	5.3	0.3	28.0	0.5	22.0	0.5	13.4	0.6
CG-112	31.5	1.8	39.7	8.7	1.9	13.0	0.9	12.3	2.0	0.2	31.3	0.3	33.3	0.8	14.3	0.7
CG-113	38.5	2.0	45.4	9.0	3.3	22.7	0.8	19.6	4.3	0.4	30.5	0.4	53.3	0.5	13.4	0.7
CG-114	41.0	1.6	39.0	11.7	2.8	20.3	0.9	18.9	6.0	0.2	30.5	0.5	49.3	1.1	15.3	0.7
CG-115	29.0	1.7	48.8	8.0	3.6	25.0	0.7	19.0	3.7	0.7	37.5	0.6	37.3	0.8	18.3	0.8
CG-118	32.6	1.7	51.1	7.7	3.8	22.0	0.9	22.0	2.0	0.6	37.8	0.4	32.7	1.3	15.3	0.6

Genotype	Leaf Length (cm)	Leaf breadth (cm)	Scape length (cm)	Number of Leaves per plant	Bulb diameter (cm)	Number of Clove	Clove weight (g)	Bulb weight (g)	Number of Bulbil/ Umbel	Bulbil Size (mm)	Dry matter (%)	Ash content (DW %)	Alcohol insoluble solids (DW %)	Total sugars (DW %)	Crude protein (DW %)	Allicin content (FW %)
CG-119	36.5	1.7	46.8	9.0	2.6	13.3	0.7	11.3	5.7	0.4	34.3	0.5	48.0	1.5	12.5	0.8
BSRG-1123	41.0	1.9	40.8	7.3	3.6	20.3	0.9	19.1	4.0	0.4	33.2	0.5	51.3	0.3	17.4	0.9
BSRG-1130	42.1	1.9	37.5	9.0	3.4	22.3	0.7	17.1	3.0	0.1	35.6	0.4	48.0	1.4	18.6	0.7
BSRG-1133	28.8	2.1	38.6	8.0	1.8	14.7	0.5	10.3	2.3	0.3	37.4	0.3	39.3	1.2	14.4	0.7
BSRG-1136	28.0	1.9	44.5	7.0	3.0	17.7	0.7	13.2	4.7	0.3	38.0	0.6	22.7	0.9	15.3	0.7
ASRG-1101	35.5	2.5	49.9	8.0	3.4	23.7	0.6	15.1	6.0	0.3	39.8	0.5	30.7	1.8	14.2	0.8
ASRG-1104	35.6	1.9	51.5	9.0	3.1	19.3	0.7	13.8	5.3	0.2	35.5	0.3	27.3	2.3	12.4	0.7
ASRG-1107	33.7	2.5	48.1	9.0	3.4	19.0	0.6	12.6	4.0	0.2	42.4	0.7	36.0	0.7	12.7	0.9
ASRG-1109	38.5	2.0	42.5	12.3	3.6	17.3	1.0	17.3	2.0	0.2	33.3	0.3	30.7	2.3	14.4	0.6
ASRG-1112	31.3	1.9	39.4	7.7	3.7	23.3	0.9	23.2	8.3	0.3	33.5	0.7	44.7	1.0	11.3	0.8
ASRG-1115	30.9	2.0	42.5	7.0	3.5	24.3	0.9	22.8	7.3	0.6	32.4	0.4	54.0	1.0	17.3	0.8
ASRG-1117	40.0	2.1	39.9	7.0	3.8	24.3	1.3	33.3	3.7	0.7	29.8	0.5	48.0	2.5	15.3	0.7
CSRG-1138	40.4	2.3	32.8	8.3	3.5	21.0	1.4	29.9	5.7	0.8	38.1	0.6	39.3	0.9	11.3	0.7
CSRG-1140	39.5	1.9	46.9	8.7	3.4	20.3	0.8	17.3	3.7	0.4	33.3	0.4	32.7	1.5	15.3	0.7

Genotype	Leaf Length (cm)	Leaf breadth (cm)	Scape length (cm)	Number of Leaves per plant	Bulb diameter (cm)	Number of Clove	Clove weight (g)	Bulb weight (g)	Number of Bulbil/ Umbel	Bulbil Size (mm)	Dry matter (%)	Ash content (DW %)	Alcohol insoluble solids (DW %)	Total sugars (DW %)	Crude protein (DW %)	Allicin content (FW %)
CSRG-1143	38.5	1.9	44.8	9.3	3.6	23.3	1.4	33.3	8.3	0.9	37.5	0.3	39.3	0.8	15.3	0.8
CSRG-1149	39.4	2.0	47.5	7.7	3.7	23.0	0.9	22.7	4.7	0.2	32.3	0.4	55.3	0.8	16.3	1.2
CSRG-1153	36.7	1.8	52.5	9.3	4.5	27.3	1.1	30.9	7.3	0.5	33.8	0.5	51.3	0.9	17.4	0.8
CSRG-1154	40.1	1.9	53.5	8.3	4.1	28.7	0.6	18.2	3.0	0.2	35.7	0.5	25.3	2.1	15.5	0.9
$C.D._{(0.05)}$	1.7	0.1	2.5	0.7	0.2	2.7	0.0	1.8	0.8	0.0	1.8	0.1	2.7	0.0	0.0	2.1

FW: Fresh weight basis DW: Dry weight basis

In this study (Table 2), genetic gain (expressed as percent of population mean) ranged from low to high in nature for different characters. The highest genetic gain was predicted for bulbil size (86.9%), bulb weight (69.6%) and clove weight (56.3%). The traits i.e. bulbil size, bulb weight remarkable high genetic gain indicated the improvement from previous generation and thus it means further improvement is possible through selection.

Burton (1952) and Johnson *et al.* (1955) stated that heritability estimates along with the knowledge of genetic gain are more useful in predicting the value of selection. Estimates of genetic gain were made for all the characters in this study and given in Table 2. Genetic advance estimates indicated that alcohol insoluble solids has potential for improvement by 20.8% while, scape length can be increased by 12.9 cm, bulb weight by 12.6 g and bulb diameter by 1.3 cm. The expected genetic advance was estimated to be quite low for the rest of the characters. In this study, number of alcohol insoluble solids, scape length and bulb weight accounted for high heritability and higher genetic advance which indicated that the expression of these characters is governed by additive gene action. Therefore, these characters can be easily improved by selection methods. Higher heritability coupled with moderate genetic advance was expressed in number of cloves, dry matter and number of bulbils per umbel providing chance for its further improvement. Higher heritability estimates and low genetic advance were obtained for ash content, allicin content, bulbils size and clove weight implies that these traits are most probably governed by non-additive gene action. The highest heritability percentage was observed for allicin content. The genotypes ASRG-1117, CSRG-1138, CSRG-1143, CSRG-1153 having highest bulb weight and less number of cloves/bulb, out of these CSRG-1143, CSRG-1153 had also moderate allicin content. For allicin extraction purpose, CSRG-1149 can be utilized. Thus CSRG-1143 and CSRG-1153 can be used by breeders for further improvement through clonal selection

REFERENCES

Avato P, Miccolis V, Tursi F (1998). Agronomic evaluation and essential oil content of garlic (*Allium sativum* L.) ecotypes grown in southern Italy. *Adv. Hort. Sci.* 12**:** 201-204.

Bradley KF, Rieger MA, Collins GG (1996). Classification of Australian garlic cultivars by DNA fingerprinting. *Aust. J. Exp. Agric.* 36: 613–618.

Burba JL (1993). Producción de "Semilla" de Ajo. Asociación Cooperadora EEA, La Consulta, Argentina.

Burton GW (1952). Quantitative inheritance in grasses. pp. 227-83. Proc 6th International Grassld Congress.

Burton GW, Devane EH (1958). Estimating heritability in tall Fescue (*Festuce arundinacua*) from replicated clonal materials. *Agron. J.* 45: 475–481.

Dubios M, Gilles KA, Hamilton JK, Roberts PA, Smith F (1956). Colorimetric method for determination of sugars and related substances. *Anal. Chem.* 26: 350-356.

Godhani PV, Singh SP (2003). Genetic variability estimation and path coefficient studies in garlic (*Allium sativum* L.) In: Singh K, Lawande K E , Pandey U B, Singh L, Bhonde S R (eds) Approaches for sustainable development in onion and garlic. pp 95-99, NHRDF, Nashik.

Gomez AK, Gomez AA (1984). Statistical procedures for agricultural research. John Willey and Sons Inc., New York, 657p.

Gupta RP, Singh DK (1998). Studies on the performance of different advance lines in garlic. *NHRDF Newsletter* 18(3): 13.

Gvozdanovic-Varga J, Vasic M, Cervenski J (2002). Variability of characteristics of garlic (*Allium sativum* L.) ecotypes. *Acta. Hort.* 579: 171-177.

Harris JC, Cottrell SL, Plummer S, Lloyd D (2001). Antimicrobial Properties of *Allium sativum* L. (garlic). *App. Micro. Biotech.* 57: 282-286.

Jafarian A, Ghannadi A, Elvasi A (2003). The effects of allicin hirtifoluim boiss on cell- mediated immune response in mice. *Ind. Iranian J. Pharn. Res.* 2: 51-55.

Johnson HW, Robinson HF, Comstock RE (1955). Estimates of genetic and environmental variability in soybean. *Agron. J.* 47: 314–318.

Jones HA, Mann LK (1963). Onions and their allies. Leonard Hill Books, London, UK.

Kamenetsky R (2007). Garlic: Botany and Horticulture. *Hort. Rev.* 33: 123-171.

Kohli UK, Frageria MS (1992). Correlation studies on some important traits in a garlic (*Allium sativum* L.) collection. *J. Res. Punjab Agric. Univ.* 20:164-166.

Kohli UK, Prabhal K (2000). Variability and correlation studies on some important traits in garlic (*Allium sativum* L.) clones. *Hsaryana J. Hort. Sci.* 29: 209-211.

Mayeux PR, Agrawal KC, Tou JSH, King BT, Lippton HL, Hyman AL, Kadowiz PJ, McNamara DB (1998). The pharmacological effects of allicin, a constituent of garlic oil. *Agents Actions* 25: 182-190.

McKenzie HA, Wallace HS (1954). The kjeldahl's determination of nitrogen. *Australian J. Chem.* 7: 55-70.

Mehta KG, Patel RH (1985). Genetic variability and path analysis in garlic. *Madras Agr. J.* 72: 691- 695.

Novak FJ (1990). *Allium* Tissue Culture. In: *Onions and Allied Crops*. Rabinowitch, H. D., and Brewster, J. L., Eds., pp. 233-250, Vol. II, CRC Press, Boca Raton, Fl., U.S.A.

Pandey UC, Singh J (1989). Performance of new varieties of garlic (*Allium sativum* L.). *Haryana Agric. Univ. J. Res.* 19: 69-71.

Pandey UC, Singh N (1987). Garlic the less problematic and most profitable crop. *Haryana Farm* 16:23-24.

Robinson RA (2007). Self-Organizing Agro-ecosystems. Sharebooks Publishing, ISBN 6980-9783634-1-3, Available: Sharebooks e-book.

Rubatzky VE, Yamaguchi M (1997). World vegetables: Principles, Production and Nutritive Values, 2nd ed., Chapman and Hall, New York.

Sayed AM, Osman SA, Ata AM, El-Nasr HS, El-Hak G (2007). Morphological, germination, bolting and cytogenetical characteristics of fourteen promising garlic genotypes. *African Crop Sci. Conf. Proc.* 8: 2005-2012.

Shankar V, Qureshi MDA, Tripathi PC, Lawande KE (1997). Micro-irrigation studies in (*Allium sativum* L.) var. G-41. *South Indian Hort.* 49:379-380.

Sterling SJ, Eagling RD (2001). Agronomic and allicin yield of Australian grown garlic (*Allium sativum.* L). *Acta Hort.* 555: 63–73.

Velisek J, Kubec R, Davidek J (1997). Chemical composition and classification of culinary and pharmaceutical garlic-based products. *Z Lebensem Unters Forsch A* 204: 161–164.

Vijay OP (1990). Note on genetic variability in garlic. *Indian J. Hort.* 47:431-433.

Woodward JR (1972). Physical and chemical changes in developing strawberry fruits. *J. Sci. Food Agric.* 23:465.

Zahedi B, Kashi AK, Zamani Z, Mosahebi GH, Hassani M (2007). Evaluation of Iranian garlic (*Allium sativum* L.) genotype using multivariate analysis methods based on morphological characters. *Biotechnology* 6: 353-356.