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Studies on the performance of some garlic genotypes (*Allium sativum* L.) under sub-tropical conditions of Himachal Pradesh

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Abstract

Twenty six genotypes of garlic collected from commercial garlic growing pockets of Himachal Pradesh were evaluated for two consecutive years. Observations were recorded on various horticultural traits. The analysis of data revealed that the germplasm differed significantly for morphological attributes, yield and storage performance. The height of the plants varied from 39.70 cm to 76.71 cm. Length and width of the individual bulb ranged from 3.69 cm to 4.96 cm and 4.00 cm to 5.33 cm, respectively. The number of cloves/bulb and individual bulb weight also varied significantly. Per hectare yield of garlic genotypes varied from 0.92 t ha^{-1} to 2.60 t ha^{-1}, lowest yield was recorded in NG-12 and highest in *Agrifound Parvati*. NG-25 had minimum storage loss (5.79%) after three months of storage. Considering yield and other parameters, the lines NG-1, NG-11, NG-25 and *Agrifound Parvati* were found promising.

Keywords: garlic, genotypes, quality, storage, yield

Introduction

Garlic (*Allium sativum* L.) is one of the important bulb crops grown and used as a spice or condiment throughout the country. India is the second largest garlic producing country after China with an annual production of 1225.50 thousand MT from 245.16 thousand hectares. In Himachal Pradesh, it is grown on an area of 3.60 thousand hectares producing 1.85 thousand MT crop annually (NHRDF, 2013). In spite of being propagated vegetatively, garlic possesses a wide range of variability on bulb traits and yield attributes as well as their storability. Existence of this natural variation suggests the possibility of improvement in garlic. Sirmour and Solan districts of Himachal Pradesh are particularly known for their garlic growing pockets. These areas have a wide diversity of garlic germplasm having desirable characteristics which can be used for selection. Selection of suitable genotypes having better storage quality for growing under subtropical conditions is required to increase the productivity of garlic. Therefore, a study was undertaken to select the better performing local genotypes and screen them for their performance in low hill areas of Himachal Pradesh.

Materials and methods

An experiment was conducted at Institute of Biotechnology and Environmental Science, Neri, Hamirour during 2010 to 2012. The experimental site is located at an altitude of 620 m above mean sea level with latitude 31°682 N and longitude 76° 522 E. The mean minimum and maximum temperature ranges between 12.4° C to 31.3° C and average humidity remains around 60.91%. The area experiences an annual rainfall of 69.4 cm, majority of which occurs during July and August months. The soil in the experimental area was clay loam with a pH of 6.6 and had 0.38% organic matter content. Soil N and P were low and K was medium. The field as well as storage studies were carried out in randomized block design (RBD) with three replications for both the years of experimentation. The garlic genotypes were selected from commercial garlic growing pockets of Himachal Pradesh falling in the Districts Sirmour, Solan and Hamirpur. The recommended variety *Agrifound Parvati* was procured from NHRDF. The cloves of these genotypes were planted at a spacing of 20 cm and 10 cm between rows and plants, respectively. Recommended cultural practices were followed to raise the crop successfully. All the observations pertaining to traits *viz*., plant height (cm), leaves plant^{-1}, leaf diameter (cm), leaf length (cm), neck thickness (cm), bulb polar diameter (cm), bulb perimeter (cm), number of cloves bulb^{-1}, weight of clove (g), total soluble solids (°B), harvest index (%), days to maturity, gross yield (q ha^{-1}) and marketable yield (q ha^{-1}) were taken by randomly selecting 10 plants from each plot. The data obtained during two years was analysed and pooled according to the standard procedure given by Gomez & Gomez (1984). After proper field curing and neck cutting, representative bulbs of these genotypes were kept in storage in perforated plastic crates for three months for both years, so as to identify superior clones under ambient conditions. Storage losses due to sprouting, rotting, physiological loss of weight (PLW) and total loss were recorded monthly for three months.

Results and discussion

Pooled analysis of variance for all the characters is presented in Table 1. The mean squares due to genotypes were found to be significant, for

Table 1. Mean square of horticultural traits of 26 accessions/lines of garlic

Trait	Source of variation			
	Replication	Accession	Error	CV (%)
Plant height	5.47	348.8*	41.69	10.58
No. of leaves plant^{-1}	1.08	14.44*	1.01	11.19
Leaf diameter	0.0051	0.32*	0.03	12.81
Leaf length	8.58	101.92*	11.60	9.27
Neck thickness	0.077	0.606*	0.065	8.79
Bulb polar diameter	0.273	1.039*	0.078	6.35
Bulb perimeter	0.003	0.431*	0.027	3.59
Cloves bulb^{-1}	68.21	84.73*	9.27	18.62
Weight of clove	0.0025	1.44*	0.023	9.25
Total soluble solids	0.56	36.22*	1.07	3.08
Yield plant^{-1}	10.60	183.84*	10.44	13.24
Biological yield plant^{-1}	43.47	217.38*	9.27	16.26
Harvest index	27.01	169.61*	58.72	9.59
Days to maturity	519.77	463.14*	10.66	2.17
Gross yield	3254.22	2991.87*	474.21	12.46
Marketable yield	414.88	4282.60*	93.52	7.21

*Significant at P<0.05

all the characters studied. This indicated a higher degree of variability among the genotypes. Figliuolo *et al.* (2001) and Tsega *et al.* (2010) also reported highly significant differences with respect to plant height, number of leaves plant^{-1}, leaf length, neck girth, number of cloves bulb^{-1}, bulb polar diameter and weight of cloves. The data pertaining to physiological parameters recorded during the two years of study are presented in Table 2. The data exhibited significant variation in different genotypes for traits. Plant height was maximum (76.71 cm) in NG-25 which was at par with *Agrifound Parvati*, NG-1, NG-4, NG-11 and NG-20. The smallest plants having height of 39.40 cm were observed in NG-12 which was at par with NG-16 and NG-24. Maximum number of leaves plant^{-1} (11.60) was noticed in *Agrifound Parvati* which was at par with NG-11, NG-20 and NG-25 though minimum leaves plant^{-1} (6.41) was observed in accession NG-12. Leaf diameter (2.03cm) was maximum in NG-25 which was at par with NG-11 and *Agrifound Parvati*. Leaf length (47.03cm) was maximum in *Agrifound Parvati* which was at par with NG-11 and NG-25.

Table 2. Pooled mean performance of garlic accessions/lines for morphological parameters

Genotype	PH (cm)	NLPP	LD (cm)	LL (cm)	NT (cm)	TSS (°B)	DTM (days)
NG-1	75.21	10.00	1.72	40.33	1.43	38.47	163.33
NG-2	62.17	10.06	1.05	38.06	1.13	29.17	158.66
NG-3	60.20	6.90	1.04	36.00	1.52	32.15	167.00
NG-4	69.53	9.56	1.57	39.23	1.42	37.72	169.33
NG-5	52.33	9.06	1.39	36.25	1.60	28.08	177.33
NG-6	59.61	10.01	1.36	32.60	1.70	36.87	174.00
NG-7	70.01	8.66	1.33	39.66	1.69	36.92	184.33
NG-8	60.51	9.03	1.21	28.00	1.81	30.25	189.00
NG-9	68.30	9.43	0.79	32.50	1.60	35.17	161.66
NG-10	69.22	10.10	1.38	38.33	1.13	34.70	167.00
NG-11	71.67	11.31	1.95	41.45	1.54	37.00	188.00
NG-12	39.70	6.41	1.61	28.05	1.67	30.62	179.33
NG-13	59.52	8.62	0.91	29.33	1.63	30.29	159.66
NG-14	54.33	10.11	1.09	28.65	1.48	32.45	166.66
NG-15	65.39	9.20	1.03	35.33	1.60	33.14	162.33
NG-16	42.16	6.76	1.06	27.05	1.67	33.73	166.33
NG-17	53.32	9.32	1.08	35.15	1.72	30.44	169.00
NG-18	62.18	10.41	0.87	33.70	1.71	32.44	170.00
NG-19	50.38	9.55	0.99	37.15	1.51	29.43	190.00
NG-20	68.83	11.00	1.29	40.15	1.62	38.29	159.66
NG-21	56.12	9.61	1.35	36.03	2.66	31.00	174.33
NG-22	67.16	6.60	1.33	36.33	1.68	33.78	165.00
NG-23	61.03	10.30	0.85	29.05	1.03	33.19	169.66
NG-24	46.83	8.92	1.47	39.66	1.56	30.15	187.00
NG-25	76.71	10.91	2.03	43.68	1.49	39.92	172.33
Agrifound Parvati	69.13	11.60	2.00	47.03	1.58	40.00	201.66
Mean	61.69	9.45	1.26	35.89	1.58	33.54	172.27
Max.	76.71	11.60	2.03	47.03	2.66	40.00	201.66
Min.	39.70	6.41	0.79	27.05	1.03	28.08	158.66
CD (P<0.05)	10.58	1.42	0.26	5.59	0.42	1.71	7.36

PH=plant height; NLPP=number of leaves plant^{-1}; LD=leaf diameter; LL=leaf length; NT=nech thickness; TSS=total soluble solids; DTM=days to maturity

Yield and its contributing traits are presented in Table 3. Maximum neck thickness (2.66 cm) was observed in genotype NG-21 which was significantly higher than all the remaining genotypes, while minimum thickness of neck (1.03 cm) was observed in NG-23. Highest bulb polar diameter (4.96 cm) was observed in NG-1 which was at par with NG-11 and NG-20. Bulb perimeter (5.33 cm) was maximum in *Agrifound Parvati* which was at par with NG-11. Maximum number of cloves bulb^{-1} (28.21) was recorded in genotype NG-3 which was at par with NG-2 and NG-16 while the minimum (8.72) cloves bulb^{-1} were observed in NG-24. Average clove weight (2.891 gm) was maximum in *Agrifound Parvati* which was significantly higher than all the remaining genotypes. It is reported that bulb weight was associated with increase in plant height, number of leaves plant^{-1}, bulb diameter, number of cloves bulb^{-1} and clove weight. This is in consonance with the findings of Dubey & Singh (2012) and Singh & Chand (2003). Maximum total soluble solids content (40.00%) was recorded in *Agrifound*

Table 3. Pooled mean performance of garlic accessions/lines for yield parameters

Genotype	NT (cm)	BPD (cm)	BP (cm)	CB	WC (g)	YPP (g)	BYPP (g)	HI (%)	Gross yield (t ha^{-1})	Marketable yield (t ha^{-1})
NG-1	1.43	4.96	4.70	16.12	2.008	32.36	36.05	89.76	2.16	1.94
NG-2	1.13	4.00	4.45	24.03	0.721	17.32	25.12	68.94	1.51	1.04
NG-3	1.52	4.33	4.06	28.21	0.856	23.96	29.00	82.42	1.68	1.44
NG-4	1.42	4.10	4.97	17.23	1.812	31.22	37.12	84.10	2.23	1.87
NG-5	1.60	3.97	4.50	11.63	1.451	16.87	23.60	71.25	1.42	1.01
NG-6	1.70	4.1 1	4.21	9.50	1.959	18.61	27.76	67.34	1.66	1.12
NG-7	1.69	4.46	4.22	21.06	1.000	21.06	32.18	65.44	1.93	1.26
NG-8	1.81	4.12	4.18	9.87	2.101	20.73	29.00	71.48	1.74	1.24
NG-9	1.60	3.69	4.92	16.38	1.156	17.73	24.41	72.63	1.46	1.06
NG-10	1.13	4.17	4.83	10.01	2.120	21.22	30.17	80.42	1.81	1.27
NG-11	1.54	4.75	5.10	14.51	2.496	36.13	42.90	85.56	2.57	2.17
NG-12	1.67	3.85	4.62	17.31	0.889	15.38	21.83	70.36	1.31	0.92
NG-13	1.63	4.41	4.11	10.20	1.603	16.35	26.55	61.59	1.59	0.99
NG-14	1.48	3.89	4.42	19.00	0.931	17.25	29.89	57.71	1.79	1.04
NG-15	1.60	3.95	4.71	14.28	1.253	17.89	28.40	62.99	1.70	1.07
NG-16	1.67	3.71	4.00	24.51	0.813	19.86	23.97	82.80	1.45	1.19
NG-17	1.72	4.27	4.41	15.01	1.224	18.37	23.77	77.28	1.43	1.10
NG-18	1.71	4.49	4.56	14.79	1.159	17.13	22.10	77.51	1.33	1.03
NG-19	1.51	4.63	4.01	9.98	2.432	24.27	31.22	77.73	1.87	1.46
NG-20	1.62	4.71	5.03	21.51	1.575	29.53	33.87	87.14	2.03	1.77
NG-21	2.66	4.41	4.99	20.00	1.241	24.82	31.16	79.65	1.87	1.49
NG-22	1.68	4.07	4.85	21.32	1.076	22.94	29.77	77.05	1.79	1.37
NG-23	1.03	3.89	5.00	19.46	1.050	20.43	25.11	81.36	1.51	1.23
NG-24	1.56	4.40	4.10	8.72	2.320	20.23	27.57	73.37	1.65	1.21
NG-25	1.49	4.35	5.00	18.73	2.052	38.43	42.23	89.11	2.51	2.29
Agrifound Parvati	1.58	3.98	5.33	14.79	2.891	43.38	48.52	89.22	2.91	2.60
Mean	1.58	4.25	4.55	16.53	1.491	22.90	29.38	75.81	1.76	1.34
Max.	2.66	4.96	5.33	28.21	2.891	43.38	48.52	89.76	2.91	2.60
Min.	1.03	3.69	4.00	8.72	0.721	15.38	21.83	57.71	1.31	0.92
CD (P<0.05)	0.42	0.46	0.27	4.99	0.25	5.30	8.09	12.58	0.58	0.45

NT=neck thickness; BPD=bulb polar diameter; BP=bulb perimeter; CB=number of cloves bulb^{-1}; WC=weight of clove; YPP=yield plant^{-1}; BYPP=biological yield plant^{-1}; HI=harvest index

Table 4. Pooled storage performance of garlic lines

Genotype	Gross yield (q ha^{-1})	Marketable yield (q ha^{-1})	After one month			After two months			After three months			
			Decay loss (%)	PLW (%)	Total loss(%)	Decay loss (%)	PLW (%)	Total loss (%)	Sprouting (%)	Decay loss(%)	PLW (%)	Total loss(%)
NG-1	216.03	194.21	0.00	0.86	0.86	0.00	2.51	2.51	1.50	0.00	6.26	7.76
NG-2	150.72	103.92	1.25	1.85	3.10	3.50	3.04	6.54	0.00	3.50	6.96	10.46
NG-3	168.00	143.85	0.00	1.90	1.90	0.00	4.26	4.26	1.25	0.00	7.89	9.14
NG-4	222.72	187.32	0.00	1.12	1.12	0.00	3.52	3.52	1.25	1.50	6.59	9.34
NG-5	141.60	101.12	2.55	2.40	4.95	4.50	4.42	8.92	0.75	4.50	8.96	14.21
NG-6	166.56	111.66	0.00	1.90	1.90	2.80	3.95	6.75	0.00	2.80	7.54	10.34
NG-7	193.08	126.36	1.50	1.38	2.88	3.50	3.01	6.51	1.50	3.50	6.87	11.87
NG-8	174.00	124.38	2.50	1.29	3.79	4.75	2.95	7.70	0.40	4.75	6.03	11.18
NG-9	146.46	106.32	0.00	1.97	1.97	1.25	4.19	5.44	2.25	1.25	9.45	12.95
NG-10	181.02	127.50	3.50	2.05	5.55	6.40	4.63	11.03	0.00	6.40	9.48	15.88
NG-11	257.40	216.78	0.00	1.06	1.06	0.00	3.10	3.10	0.00	0.00	6.82	6.82
NG-12	130.98	92.33	0.00	1.58	1.58	1.25	3.12	4.37	2.30	1.25	6.48	10.03
NG-13	159.33	98.56	1.50	1.92	3.42	2.50	4.21	6.71	0.00	2.50	8.85	11.35
NG-14	179.34	103.50	2.25	1.96	4.21	5.50	3.27	8.77	3.25	5.50	7.26	16.01
NG-15	170.40	107.34	1.05	2.31	3.36	3.50	4.58	8.08	0.00	3.50	9.36	12.86
NG-16	144.82	119.16	0.00	1.47	1.47	1.80	4.07	5.87	1.25	1.80	9.68	12.73
NG-17	142.62	110.23	0.00	1.47	1.47	2.25	3.96	6.21	0.00	2.25	8.57	10.82
NG-18	132.60	102.78	0.00	2.56	2.56	0.75	5.26	6.01	0.75	0.75	10.14	11.64
NG-19	187.32	145.59	0.00	1.42	1.42	0.50	4.27	4.77	1.30	0.50	9.67	11.47
NG-20	203.22	177.18	0.00	1.20	1.20	0.00	2.98	2.98	0.00	1.00	6.86	7.86
NG-21	186.96	148.92	0.00	2.12	2.12	1.25	5.29	6.53	0.00	1.25	11.15	12.40
NG-22	178.62	137.00	1.60	1.45	3.05	3.60	3.52	7.12	2.60	3.60	7.85	14.05
NG-23	150.66	122.98	2.50	2.02	4.52	4.25	4.85	9.10	3.25	4.25	9.75	17.25
NG-24	165.42	121.38	3.42	1.49	4.91	6.40	3.98	10.38	2.80	6.40	8.81	18.01
NG-25	251.38	228.68	0.00	1.00	1.00	0.00	2.01	2.01	0.00	0.00	5.79	5.79
Agrifound Parvati	291.12	260.27	0.00	0.98	0.98	0.00	1.82	1.82	0.90	1.30	5.85	7.15
CD (P<0.05)	35.75	25.88	1.21	NS	1.12	2.13	2.37	1.78	1.77	2.08	2.11	2.21

PLW=Physiological loss of weight; Note: No sprouting was noticed up to two months

Parvati followed by NG-25. Maximum yield plant^{-1} i.e. highest weight of bulb (43.38 gm) was noticed in *Agrifound Parvati* and was at par with genotype NG-25 while the lowest weight of bulb (15.38gm) was found in NG-12. Highest harvest index (89.76%) was recorded in NG-1 followed by *Agrifound Parvati*. The accession NG-2 took minimum (158.66 days) to maturity followed by NG-15. The results revealed that *Agrifound Parvati* recorded maximum (2.60 q ha^{-1}) marketable yield which was significantly higher than all the genotypes while minimum yield (0.92 q ha^{-1}) was recorded in genotype NG-12. Higher bulb weight was found to be directly proportional to the total yield in the present experiment. The results of present study are in conformity with those of Shri Dhar (2002).

The storage data presented in Table 4 revealed that after one month of storage no sprouting was observed for all the genotypes though some of the genotypes show decay loss. The genotype NG-1 showed minimum physiological loss of weight (0.86%) followed by *Agrifound Parvati* (0.98%) and NG-25 (1.00%). Even after two months of storage no sprouting was observed in any of the genotype but maximum genotypes showed decay loss except NG-1, NG-3, NG-4, NG-11, NG-20, NG-25 and *Agrifound Parvati*. The minimum physiological weight and total loss (1.82%) was noted in genotype *Agrifound Parvati* followed by genotype NG-25 (2.01%). After three months of storage some of the genotypes showed sprouting. Minimum physiological loss of weight and total loss (5.79%) was noted in genotype NG-25 whereas, the maximum weight loss was found in NG-21 (11.15%) while maximum total loss 18.01% was observed in accession NG-24. NG-11, *Agrifound Parvati* and NG-25 had high total soluble solids and minimum total losses after three months of storage, indicating that the lines having high total soluble solids can be stored for longer duration. This is in confirmation with the results obtained by Dubey & Singh (2012). It is clear from the field and storage data that the lines NG-1, NG-11, NG-25 and *Agrifound Parvati* performed better than the other genotypes.

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