Original Research Article

Comparative performance response of ten economically important garlic cultivars in alluvial soils of Punjab

Abstract

All the varieties are not performed equally in all the agroclimatic and soil conditions. A field experiment was conducted at the Agricultural farm of the Lovely Professional University, Punjab to evaluate the growth and yield performance of garlic cultivars in alluvial soil of Punjab. T Ten cultivars *viz.*, Fewari, G-50, G-323, G-189, G-1, Parvati-2, G-389, G-384, G-282, and G-404 were considered as experimental treatments, The experiment was arranged in a randomized complete block designand replicated thrice. Growth, yield attributes and yield were significantly varied among the varieties.. Garlic productivity has been declining and more improved breeding lines are required to enhance the productivity status. The selected cultivars were prominent among farmers and identifying the variation among germplasms may aid in genetic improvement among garlic cultivars. Plant height after 30 days of sowing shows significant difference among cultivars; the pseudo-stem length of G-389 cultivar recorded higher values as compared to others. Yield parameter like length of bulb, bulb width and clove length were recorded higher for Fewari and Parvati-2 cultivars. The cluster analysis based on growth and yield parameters segregates into two major clusters, *viz.*, Fewari in one major cluster and the second cluster is segregated into further sub-clusters; sub-cluster 1 in second major cluster segregates G1, Parvati-2, G-189, and G-389 cultivars; however the sub-cluster 2 in second major cluster segregates G-323, G-282, G-384, and G-50 cultivars. Principal component analysis (PCA) show the close similarity between G-389 and G-189 cultivars and Fewari cultivars show high variation as compared to all other cultivars..

Key Word: Garlic, Genetic Variability, Cluster Analysis, Principal Component Analysis.

Introduction

Garlic (*Allium sativum* L.) has its place in the Alliaceae family and the genus Allium; classified as the second most widely cultivated bulb crop after onion **(Assefaet al., 2015)**. Cultivated garlic is known for at least 5000 years ago in India and Egypt; and understood to originate in Central Asia, someplace garlic grown in the wild and consumed in early as 2780 BC. Garlic is grown all over the world from temperate to subtropical climates. Garlic is one of the most broadly cultivated vegetables in the world and it ranks in a high economic position among all vegetables, and spices are grown in India, (**Mario et al.**, 2007; **Malik et al.**, 2013). The value of garlic as a crop has been recognized from very ancient times; it is rich in proteins (1.5-2.1%), minerals (0.7%) (phosphorus, calcium, magnesium) and carbohydrates (26- 30%), lipid (0.1-0.2%), fiber (1-5%), nitrogen (0.6-1.3%), total oil-soluble compounds (0.15%). It also contains fat, vitamin C (0.015%) and sulphur (0.23-0.37%).

Garlic productivity in our nation gradually declining as compared to other garlic producing nations (Malik et al. 2017; Singh et al. 2012) and similar trends of lower productivity in Punjab besides alluvial soils which are considered to be the best soil comprising all nutrients and highly fertile. In such scenario it is necessary to evaluate and characterise the garlic germplasms according to their agronomic production. Recording garlic cultivars growth parameters performance at different intervals would be an efficient indicator to correlate agronomic and genotype for the cultivars (Bathh et al. 2013)

Garlic shows wide morphological and agronomic variations in color and size of bulb, plant height, flowering, number and size of the cloves, days to harvesting, resistance to storage capacity, dormancy, and adaptation to agro-climatic situations **(Singh et al., 2011)**. All Allium crops originate from the main center of *Allium* diversity that stretches from the Mediterranean basin to central Asia. The *santorum* variety, or common garlic, produces a weak flower stalk, if it bolts, and has a bulb with many pure white or pink blushed bulbils. Cultivated garlic cultivars are sexually sterile and are therefore vegetatively propagated for commercial production (**Osman et al.2007**). The genus Allium L. (Alliaceae) exhibits great diversity in various morphological characters, particularly in life form (bulb) and ecological habitat. It is of major economic importance as a vegetable and herbal crop and ornamental plant. This genus consists mostly of perennial and bulbous plants and it is widely distributed over Holarctic regions from the dry subtropics to the boreal zone. (**Mir et al., 2013**).

Garlic displays a wide range of variations under various ecological conditions, and some germplasm has adapted to specific environments through artificial and natural selection. The agri-

cultural traits of garlic germplasm have normally shown wide variations in characteristics such as bulb weight, coat layer, leaf length, growth habit, and stress resistance (**Chen et al., 2013**). Variability is a desirable goal in germplasm collection since the materials conserved in such a collection represent the stock material for the breeding program. Hence, the knowledge of the interrelationships among and between yields and yield components is necessary; the determination of correlation between vegetative characteristics is a matter of considerable importance in the selection of correlated responses among different cultivars (**Pervin et al., 2014**).The present study evaluates the performance of garlic varieties and select the suitable ones in alluvial soils in Punjab, India.

Materials and Methods

Selection of Genotypes:

The different plant genotypes of garlic bulbs were collected **(Table 1)** from the Directorate of Onion and Garlic Research (DOGR), Rajgurunagar, Pune, and the National Horticultural Research and Development Foundation (RDF), Lasalgaon, Maharashtra, India. Each genotype of garlic selected **(Figure 1)** are highly significant and most popular among the farming communities of India due to their respective economic importance.

Experimental Design

This experiment was conducted in the agricultural research field of the Lovely Professional University Department of Agriculture (Genetic and Plant Breeding), Phagwara, Punjab, India (Longitude 75° 46’ 10E, Latitude of 31° 13’4N an altitude of 233m above from sea level) in autumn to winter of 2015-16 and the average annual rainfall in the district is 703.0 mm. The ten garlic cultivars were considered as treatments. The experiment was laid out in a randomized complete block design with three replications. The unit plot size was 14m x 6m keeping a spacing of 1 m and 0.5 m between block to block and plot to plot. The cloves were planted at a spacing of 10cm and 7cm between row to row and clove to clove which accommodates 40 plants per plot. The experimental field area was covered under the sub-tropical continental monsoon-type climate of Punjab and the central plain zone of the state Agro-climatic zone. The field was plowed using a moldboard plow and tilled using a cultivator 3-4 times to eliminate debris and soil clods. FYM 20 t/ha was incorporated at the time of the last plowing and beds of appropriate size are prepared after leveling.

Table 1: List of Genotypes

No	Genotypes	Bulb Characteristics	cloves/blub
1	**Fewari**	Bigger bulbs, pinkish-white color, compact cloves. Very complex flavors.	9-10
2	**G-50**	Bulbs are compact, attractive white creamy flesh, and their average diameter is 3.5-4.0 cm.	35-40.
3	**G-323**	Bulbs are silvery-white and their average diameter is 3.5-4.0 cm.	20-25
4	**G-189**	Bulbs are creamy-white and bigger sized 4.55 cm in diameter.	22-30.
5	**G-1**	Bulbs are compact, silvery-white skin with creamy flesh. Sickle-shaped cloves with a diameter of 4.0-4.5 cm.	25-30
6	**Parvati-2**	Bulbs are bigger 5.0-6.0 cm in diameter and creamy white.	12-14
7	**G-389**	Bulbs are compact, silvery-white with creamy flesh and bigger elongated cloves with a diameter of 3.5 to 4.5 cm.	20-25
8	**G-384**	Bulbs are bigger size 5.0-6.5 cm in diameter, creamy white color with a pinkish tinge.	10-16
9	**G-282**	Bulbs are creamy-white and bigger sized about 4.56 cm in diameter.	15-16.
10	**G-404**	It is moderately resistant to purple blotch. Bulbs are compact and bold weighing 18-20g. The cloves are light purple.	15-18

Figure 1: Ten different Garlic Cultivars: A)Fewari, B) G-50, C) G-323, D)G-189, E) G-1, F) Parvati-2, G)G-389, H) G-384, I)G-282, J)G-404

Planting

Individual cloves from seed garlic bulbs were separated but not long before planting. Twist off the outer skins and take the cloves apart without breaking the basal plate of the cloves, as that makes them unusable for planting. Big cloves (>1.5g) should be selected for planting. Small and damaged cloves should be rejected. The seed rate for garlic is 400-500 kg/ha. Selected cloves should be planted vertically 2 cm below the soil surface with a plant-to-plant spacing of 7 cm and row-to-row spacing of 10 cm.

Morphological Studies:

Recording of observations:

Five plants were selected from each plot and observations were recorded on the following characters on plants in each entry of treatment and all replication. Data recording based on their Phenotypic and Genotypic characters. The parameters are shown below:

30, 45, 60, 90, and 120 Day interval Data noted on: Plant Height, Total Number of Leaf, Length of Leaf, Width of leaf, pseudo tem Length, pseudostem Width, Total Number of Plants per plot, and plant color. Plant height after 30, 45, 60, 90, and 120 days: Total plant height was measured by scientific measuring tape. (from ground level to the top of the central apical shoot), Count the total number of leaf bottom up to the top, measure the leaf length with help of a scientific measuring tape, measure the width of the leaf with help of a vernier caliper, take the length of pseudos tem by scientific measuring tap, pseudostem width count by vernier caliper, counting the total number of plants per plots and to check the plant color.

Measurements and estimates of plant by (Badran et al (2015) **:**

Characteristics of plant growth were measured as follows:

1) Plant height (cm) at harvest (from the surface of the soil to the highest point of the plant)
2) Fresh weight per plant (g/plant) after harvesting.
3) Dry weight per plant the sample was dried in sunlight for 10 days and weighed by sensitive balance (g/plant).
4) Bulb diameter (cm) was calculated according to Mann (1952) using vernier caliper.
5) Bulb weight (g) was harvested when the leaves turned yellowish and left in the air for two or three weeks after the harvesting of garlic.

After 120 Day interval Data was noted on: length of the bulb, the width of the bulb, cloves length, cloves width, cloves weight, the total number of cloves, 10 bulb weight with leaf, 10 bulbs dry weight, 10 bulb weight without leaf, the weight of one bulb, presence of bulbils, and color of bulbils.

Statistical Analysis

The collected data were compiled and analyzed following analysis of variance (One-way ANOVA) using computer software SPSS version 16. The comparison among the treatment means were done by Duncan;s multiple range test (DMRT). Mean values by one-way ANOVA were subjected to principal component analysis (PCA) and hierarchical clustering by the Wards method was performed by PAST 3. x statistical software.

Result and Discussion

Garlic Cultivars Growth Parameters

The plant height initially showed no significant variation among the garlic cultivars; however at 45 days variation has been recorded as variety Parvati-2 and G-389 showed maximum significant plant height (38.8a and 38.96a respectively) and the lowest value recorded for varieties G-323 and G-404 (30.7c and 29.82c respectively). At 60 days garlic plant height is maximum for G-389 and lowest for G-323 (42.10a and 31.73c respectively). The maximum plant height recorded at 90 days of garlic for variety G-189 and the lowest for Fewari (56.45a and 40.46b). At 120 days, plant height recorded for the variety G-189 showed maximum and Fewari showed the lowest height (80.06a and 49.73b) (**Table 2)**. The plant height variation is due the genetic difference among the cultivars and consequently the difference in response. In a similar study Khar et al., 2005 reported that plant height was more stable in the varieties Parvati-2, G-1, G-282, and G-323, whereas the taller plant height was recorded for varieties Fewari, G-50, G-189, and G-389. The varieties G-404 and G-384 were seems unstable and unpredictable may be due to environmental concerns. Plant

height variation among the cultivars implicates the chances for improvement of agronomic traits in garlic At 30-day variety Fewari showed maximum number of leaves and G-404 variety showed the minimum number of leaves . Significantly higher number of plant leaves at 45 days was found for the Fewari variety and for G-404 fewer leaves were recorded (6.20a and 4.33d). At 60 days the number of plant leaves recorded maximum for G-384 variety and minimum plant leaves recorded for G-404 variety (7.20a and 5.20c). Moreover, at 90-day and 120-days the number of leaves was found higher for variety Fewari and less number of leaves was observed for variety Parvati-2 (10.06a and 7.73b). All varieties showed the variation in different days of interval in **Table 3**. Similarly Singh *et al*., 2012; Agarwal and Tiwari 2009; reported more number of garlic leaves stable in the varieties in Fewari and G-384 whereas G-404 and Parvati-2 exhibited stable performance for less number of leaves.

Table 2: Plant height among different cultivars in different intervals

Treatments	Plant Height 30 DAS	Plant Height 45 DAS	Plant Height 60 DAS	Plant Height 90 DAS	Plant Height 120 DAS
Fewari	$29.13^{a}\pm1.05$	$37.40^{ab}\pm1.41$	$37.32^{abc}\pm2.14$	$40.46^{b}\pm1.27$	$49.73^{b}\pm1.53$
G-50	$29.21^{a}\pm1.35$	$35.64^{ab}\pm0.54$	$39.53^{ab}\pm0.67$	$51.90^{a}\pm0.98$	$77.73^{a}\pm5.42$
G-323	$28.28^{a}\pm1.50$	$30.70^{c}\pm1.45$	$31.73^{c}\pm2.56$	$50.50^{a}\pm3.11$	$75.66^{a}\pm3.20$
G-189	$29.00^{a}\pm0.39$	$36.46^{ab}\pm0.65$	$38.23^{ab}\pm2.57$	$56.45^{a}\pm3.14$	$80.06^{a}\pm3.17$
G-1	$28.88^{a}\pm1.63$	$33.76^{bc}\pm1.53$	$35.53^{bc}\pm0.72$	$49.16^{a}\pm1.37$	$71.26^{a}\pm1.33$
Parvati-2	$28.01^{a}\pm0.49$	$38.86^{a}\pm1.71$	$36.00^{bc}\pm1.11$	$52.50^{a}\pm0.87$	$77.60^{a}\pm3.95$
G-389	$29.28^{a}\pm1.51$	$38.96^{a}\pm1.89$	$42.10^{a}\pm0.60$	$54.97^{a}\pm4.50$	$79.13^{a}\pm2.82$
G-384	$27.99^{a}\pm0.05$	$36.26^{ab}\pm1.67$	$35.60^{bc}\pm2.87$	$50.63^{a}\pm4.09$	$76.86^{a}\pm3.17$
G-282	$28.98^{a}\pm1.82$	$37.73^{ab}\pm1.52$	$39.10^{ab}\pm0.86$	$53.66^{a}\pm2.06$	$76.73^{a}\pm2.81$
G-404	$27.00^{a}\pm2.35$	$29.82^{c}\pm0.89$	$33.86^{bc}\pm0.43$	$50.86^{a}\pm1.30$	$71.20^{a}\pm2.19$

Table 3: Effects of Leaves Numbers on different days of interval

Treatments	Leaves No. 30 DAS	Leaves No. 45 DAS	Leaves No. 60 DAS	Leaves No. 90 DAS	Leaves No. 120 DAS
Fewari	5.46^{a}±0.37	6.20^{a}±0.30	6.73^{ab}±0.40	7.66^{ab}±0.13	10.06^{a}±0.17
G-50	4.93^{a}±0.29	5.40^{ab}±0.20	6.73^{ab}±0.56	7.93^{a}±0.17	8.53^{b}±0.46
G-323	4.73^{a}±0.06	4.40^{cd}±0.23	5.53^{bc}±0.26	7.66^{ab}±0.24	8.33^{b}±0.76
G-189	5.40^{a}±.11	5.13^{bcd}±0.17	7.13^{a}±0.66	7.60^{ab}±0.11	8.93^{b}±0.52
G-1	5.26^{a}±0.17	5.00^{bcd}±0.11	6.93^{ab}±0.46	8.00^{a}±0.20	8.33^{b}±0.13
Parvati-2	5.20^{a}±0.50	5.13^{bcd}±0.46	6.40^{abc}±0.41	7.53^{ab}±0.06	7.73^{b}±0.37
G-389	4.73^{a}±0.17	5.66^{ab}±0.24	7.13^{a}±0.06	7.53^{ab}±0.26	8.13^{b}±0.06
G-384	5.40^{a}±0.11	5.26^{bc}±0.37	7.20^{a}±0.30	7.73^{ab}±0.13	8.20^{b}±0.30
G-282	5.06^{a}±0.24	4.80^{bcd}±0.30	6.86^{ab}±0.43	7.93^{a}±0.13	8.06^{b}±0.24
G-404	4.53^{a}±0.35	4.33^{d}±0.17	5.20^{c}±0.46	7.33^{b}±0.17	8.13^{b}±0.06

At 45 days the length of leaves for the G-282 variety was found significantly higher and significantly lower for the G-404 variety(36.13a and 26.66c). At 90 days higher leaf length was observed for the variety G-389 and lower for variety Fewari.(45.60a and 36.56b). At 120 days variations of leaves length for variety G-189 was recorded highest and for the variety Fewari recorded lowest leaf length (51.80a and 41.53b). (**Table 4).** Similar garlic genetic performance studies by **Khar *et al.*, 2005; Silva *et al.*, 2015**; revealed that maximum leaves length was recorded for G-282, G-389, and G-189 whereas the minimum leaves length is recorded in G-50, G-404, and Fewari. Higher leaf length trait may be attributed to certain garlic cultivars due to inheritance and high variation response to environmental factors. The garlic leaf's width recorded at the 30 days interval; the varieties was not any significant difference. At 45 days and 65 days interval, expect Fewari

variety all other varieties show no or less variation for leaf width. However at the 90 days interval (**Table 5**) significant variation has been recorded; variety G-404 shown more leaves width and lower leaf width for variety G-384 was found (2.63a and 1.79a). Also, **Khar et al., 2005; Silva *et al.*, 2014**; concluded the garlic width leaves higher showed in varieties Fewari and G-404 whereas lower width of leaves G-404 and G-384.

Table 4: Effects of Leaves Length on different days of interval

Treatments	Leaves Length at 30 DAS	Leaves Length at 45 DAS	Leaves Length at 60 DAS	Leaves Length at 90 DAS	Leaves Length at 120 DAS
Fewari	27.92^{ab}±0.30	34.10^{ab}±0.95	31.36^{ab}±1.36	36.56^{b}±.24	41.53^{b}±1.87
G-50	25.71^{b}±1.66	34.80^{a}±1.00	34.13^{ab}±1.84	44.60^{a}±3.20	47.46^{a}±1.12
G-323	26.83^{ab}±0.79	29.80^{bc}±1.45	28.20^{b}±3.10	41.83^{ab}±1.84	50.53^{a}±0.65
G-189	27.54^{ab}±0.90	33.76^{ab}±0.52	35.10^{a}±2.31	44.06^{ab}±3.43	51.80^{a}±1.41
G-1	27.18^{ab}±0.85	31.70^{ab}±2.00	31.80^{ab}±0.45	38.70^{ab}±1.44	47.86^{a}±0.54
Parvati-2	27.43^{ab}±0.53	34.63^{a}±1.31	33.10^{ab}±1.35	42.16^{ab}±2.46	50.60^{a}±0.52
G-389	28.22^{ab}±0.62	35.76^{a}±0.16	36.03^{a}±0.72	45.60^{a}±0.35	50.33^{a}±1.91
G-384	28.25^{ab}±0.82	32.16^{ab}±2.31	33.30^{ab}±2.29	39.33^{ab}±3.87	51.26^{a}±0.17
G-282	28.96^{a}±0.38	36.13^{a}±1.63	34.16^{ab}±1.40	42.80^{ab}±2.02	51.46^{a}±1.22
G-404	27.40^{ab}±0.48	26.66^{c}±1.12	28.20^{b}±1.22	38.66^{ab}±0.86	49.00^{a}±2.30

Table 5:Effects ofLeaves Widthon differentdaysofinterval

Treatments	Leaves width at 30 DAS	Leaves width at 45 DAS	Leaves width at 60 DAS	Leaves width at 90 DAS	Leaves width at 120 DAS
Fewari	0.75a±.07	1.50a±0.0	1.45a±0.06	2.30a±0.03	3.17a±0.1
G-50	0.74a±.02	1.18abc±0	1.30ab±0.0	1.93a±0.10	2.02b±0.02
G-323	0.72a±.05	1.08bc±0.1	1.16bc±0.0	1.94a±0.10	2.07b±0.14
G-189	0.77a±.05	1.16bc±0.1	1.32ab±0.05	2.16a±0.06	1.98b±0.25
G-1	0.78a±.00	1.24ab±0.1	1.22bc±0.0	1.92a±0.04	2.03b±0.08
Parvati-2	0.78a±.03	1.25ab±0.0	1.22bc±0.0	2.00a±0.00	2.07b±0.13
G-389	0.72a±.06	1.25ab±0.0	1.31ab±0.0	2.02a±0.02	1.83b±0.27
G-384	0.78a±.04	1.25ab±0.1	1.29ab±0.0	1.79a±0.12	1.63b±0.05
G-282	0.73a±.01	1.32ab±0.1	1.34ab±0.0	2.00a±0.13	1.73b±0.09
G-404	0.70a±.01	0.88c±0.0	1.05c±0.0	2.63a±0.9	1.63b±0.11

At 30-day, 45-days and 60-days after sowing the pseudo stem length was found significantly higher for G-389 variety and found lower for variety Fewari. Also at 90 days intervals, G-389 higher Psudostem lengths was recored for G-389, G-50, G-323 (17.63bc) and lower pseudo stem length was for Fewari found lowest (**Table 6).** The results observed are in accordance with **Nair *et al.*, 2014; Azuara *et al.*,2008**; where they reported that the Psudostem length was found higher for G-389, G-50, and G-323 variety and lower for Fewari.At the 30 days, the Psudostem diameter for G-282 variety was found significantly higher and lower for G-404 variety. However, at 45 days interval, the Psudostem diameter not varied for all varieties and the trend changes at 60-days inter-

val where the variety G-389 found higher pseudo stem diameter. At 90 days intervals, Psudostem diameter was found maximum for variety G-50 and found minimum for Parvati-2 variety. At 120 days of the interval, the Psudostem diameter was found significantly higher for variety Fewari and found lower for variety G-404. All variables are significant in each other to higher than lower as shown in (**Table 7).** Similar studies by **Rakesh, 2016; Panthee et al.,2006; Batth et al 2013**; reported the higher Psudostem diameter for variety G-282, G-189, G-50, and Fewari and the lower Psudostem diameter for variety G-404, Parvati-2.

Table 6: Effect of Pseudostem Length different days of interval

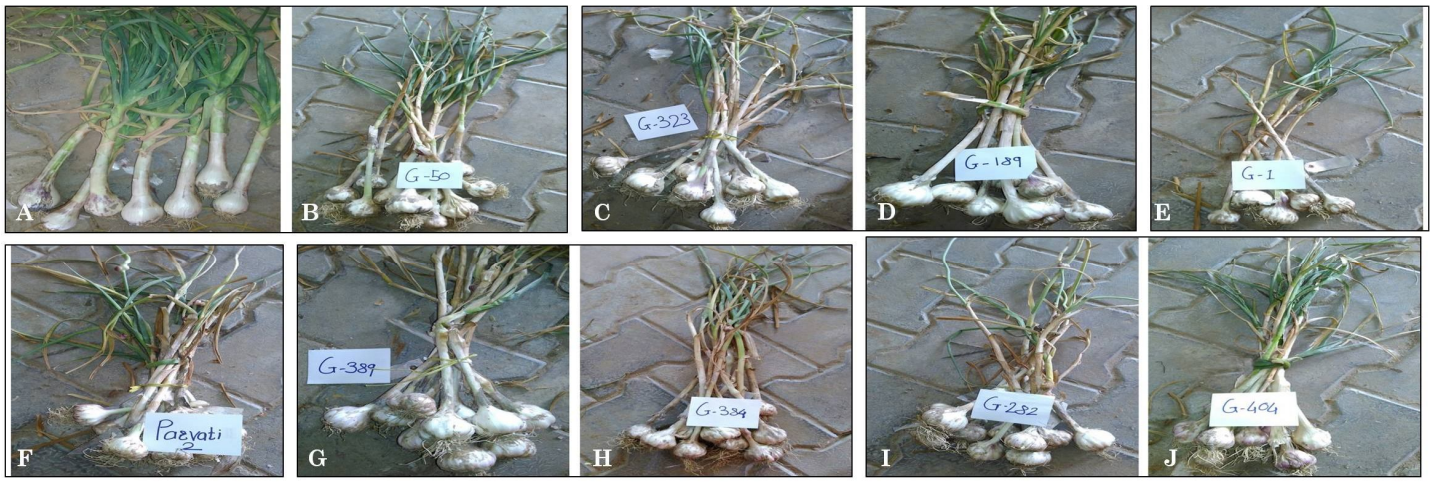
Treatments	Pseudostem Length at 30 DAS	Pseudostem Length at 45 DAS	Pseudostem Length at 60 DAS	Pseudostem Length at 90 DAS	Pseudostem Length at 120 DAS
Fewari	$2.46^{c}\pm0.46$	$3.33^{d}\pm0.52$	$4.72^{d}\pm0.83$	$6.33^{d}\pm0.98$	$10.00^{c}\pm0.52$
G-50	$8.00^{b}\pm1.40$	$11.40^{bc}\pm1.30$	$15.26^{bc}\pm2.75$	$17.26^{bc}\pm2.02$	$28.53^{ab}\pm0.56$
G-323	$7.43^{b}\pm0.85$	$9.80^{c}\pm0.60$	$13.80^{c}\pm0.60$	$17.63^{bc}\pm1.12$	$26.26^{ab}\pm1.37$
G-189	$7.70^{b}\pm.2.82$	$9.83^{c}\pm3.00$	$16.13^{bc}\pm1.31$	$19.06^{b}\pm0.75$	$28.13^{ab}\pm3.13$
G-1	$7.00^{b}\pm0.70$	$9.50^{c}\pm0.26$	$12.13^{c}\pm0.63$	$14.53^{c}\pm1.15$	$26.80^{ab}\pm0.61$
Parvati-2	$9.00^{b}\pm0.94$	$12.06^{bc}\pm0.98$	$14.93^{bc}\pm0.88$	$18.80^{b}\pm0.80$	$30.33^{a}\pm2.24$
G-389	$14.13^{a}\pm1.67$	$18.53^{a}\pm2.03$	$22.26^{a}\pm1.22$	$25.53^{a}\pm1.45$	$31.66^{a}\pm2.20$
G-384	$10.93^{ab}\pm1.07$	$14.13^{b}\pm0.24$	$18.36^{b}\pm1.02$	$20.00^{b}\pm0.70$	$30.60^{a}\pm2.25$
G-282	$9.66^{b}\pm0.26$	$12.40^{bc}\pm0.30$	$15.26^{bc}\pm0.86$	$18.33^{b}\pm0.69$	$27.20^{ab}\pm1.66$
G-404	$7.80^{b}\pm0.30$	$10.20^{bc}\pm0.30$	$13.46^{c}\pm0.26$	$16.86^{bc}\pm0.24$	$24.33^{b}\pm0.29$

Table 7: Effect of Pseudostem Diameter on different days of interval

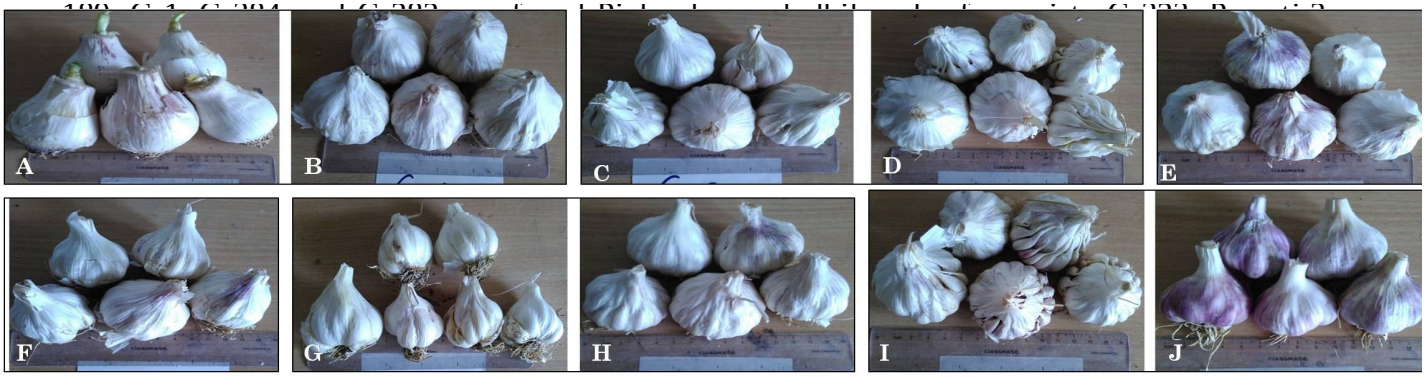
Treatments	Pseudostem Diameter at 30 DAS	Pseudostem Diameter at 45 DAS	Pseudostem Diameter at 60 DAS	Pseudostem Diameter at 90 DAS	Pseudostem Diameter at 120 DAS
Fewari	0.60^{a}±0.02	0.84^{ab}±0.02	1.14^{ab}±0.09	1.39^{b}±0.09	1.74^{a}±0s.10
G-50	0.62^{a}±0.04	0.83^{ab}±0.04	1.15^{ab}±0.06	2.20^{a}±0.70	1.52^{ab}±0.04
G-323	0.55^{a}±0.07	0.81^{ab}±0.05	1.11^{ab}±0.04	1.38^{b}±0.04	1.48^{ab}±0.08
G-189	0.55^{a}±0.10	0.84^{ab}±0.05	1.24^{a}±0.06	1.56^{ab}±0.07	1.60^{ab}±0.10
G-1	0.86^{a}±0.33	0.81^{ab}±0.02	1.11^{ab}±0.02	1.31^{b}±0.03	1.50^{ab}±0.05
Parvati-2	0.60^{a}±0.02	0.79^{ab}±0.02	1.01^{b}±0.02	1.20^{b}±0.02	1.46^{ab}±0.16
G-389	0.99^{a}±0.46	0.80^{ab}±0.01	1.14^{ab}±0.02	1.38^{b}±0.01	1.40^{bc}±0.06
G-384	0.88^{a}±0.20	0.85^{ab}±0.01	1.15^{ab}±0.01	1.35^{b}±0.01	1.42^{bc}±0.04
G-282	1.00^{a}±0.43	0.86^{a}±0.04	1.22^{a}±0.02	1.46^{b}±0.03	1.38^{bc}±0.04
G-404	0.52^{a}±0.07	0.72^{b}±0.06	1.02^{b}±0.04	1.21^{b}±0.07	1.16^{c}±0.05

Garlic Cultivars Yield Parameters

The length of bulb (**Figure 2**)was found high for Fewari variety and low for G-404 variety (5.14a and 3.52c) and all other cultivars are in similar range with no significant difference. The bulb width was found more for Parvati-2 variety and less for G-404 (7.81a and 3.71a). The cloves length of garlic was found more for Fewari variety and less for G-282 and G-404 (5.14a, 2.44c and 2.40c). The cloves width of garlic was found significantly higher for Fewari variety and lower for G-282 variety (5.26a and 0.85c). 1 cloves weight (**Figure 3**) of garlic was found higher for Fewari variety and lower for G-404 cultivar (42.73a and 1.58b). The total number of cloves was found higher for G-1 variety. The results are in accordance with NairNair at al., 2014; Volk M. V. 2009; Hazem A. O. A. 2013 and revels that morphological characteristics of cultivars are strongly linked with genetic traits; however variation in morphological attributes can occur due to environmental



Harvest of Ten Different Garlic Cultivars. A) Fewari B) G-50 C) G-323, D) G-189 E) G-1 F) Paravati-2 G) G-389 H) G-384 I) G-282 J) G-404



Blubs of Ten Different Garlic Cultivars after Harvest. A) Fewari B) G-50 C) G-323, D) G-189 E) G-1 F) Paravati-2 G) G-389 H) G-384 I) G-282 J) G-404

Figure 2 : Harvest of Ten Garlic Cultivars and Garlic Bulbs after Harvest

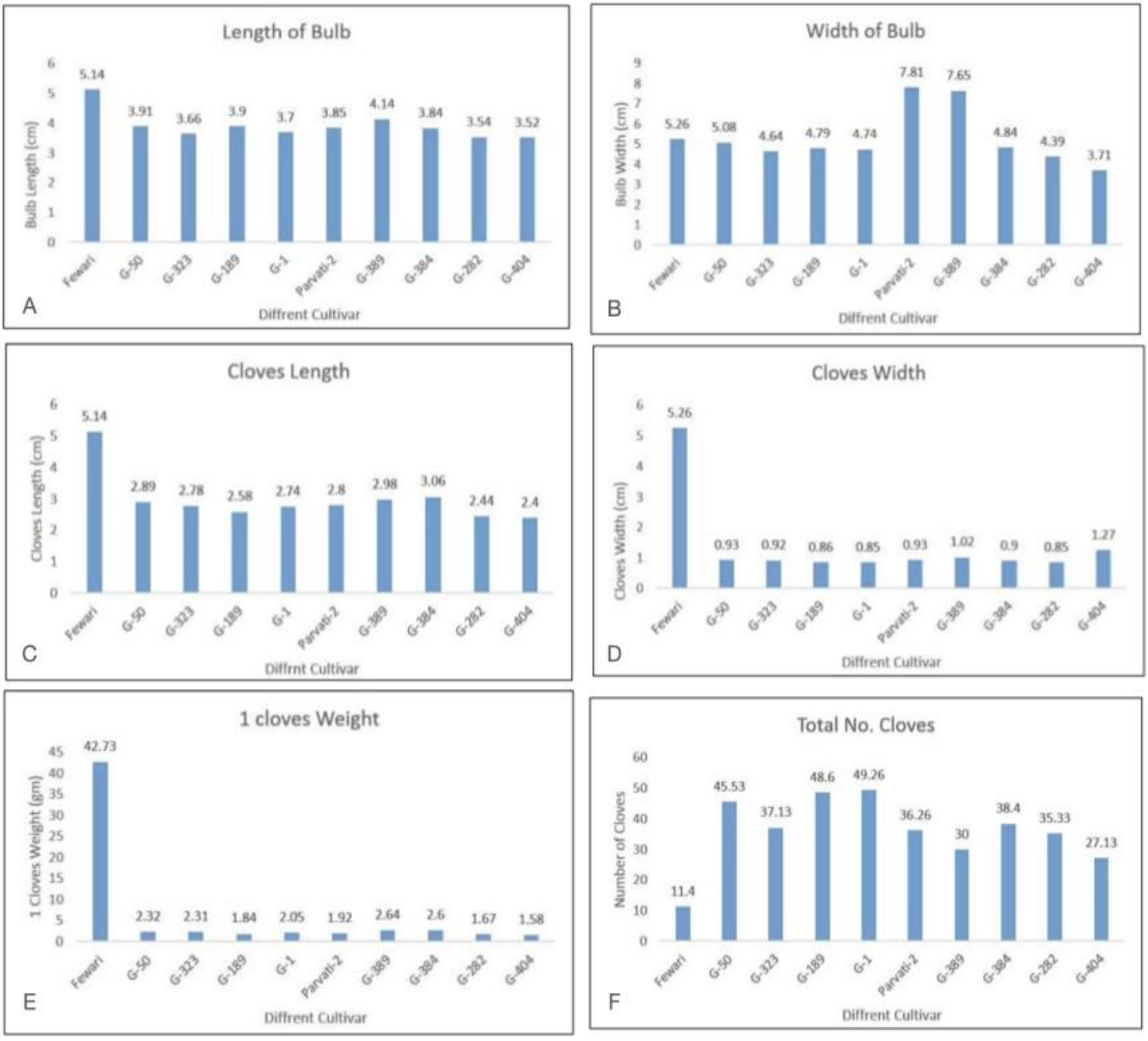


Figure 3: Yield attributes of differ garlic cultivars grown in the alluvial soil in Punjab A) Length of Bulb; B) Width of Bulb; C) Clove length; D) Clove width; E) 1 Clove weight; F) Total number of cloves

Treat-ments	10 Bulb with Leaves Weight	10 Dry Bulb Weight	10 Bulb Weight	1 Bulb Weight	Total N Plants/pl
Fewari	1.52^{c}±.07	780.00^{a}±15.27	6.50^{a}±28.86	60.00^{a}±5.77	33.40^{a}±1.
G-50	7.40^{a}±32.14	486.66^{b}±36.66	4.36^{b}±34.80	41.66^{a}±18.33	31.46^{a}±2.
G-323	5.33^{ab}±12.01	373.33^{b}±29.05	3.06^{bc}±20.27	43.33^{a}±3.33	37.26^{a}±1.
G-189	5.86^{ab}±98.20	426.66^{b}±86.85	3.23^{bc}±47.02	43.33^{a}±6.66	29.73^{a}±5.
G-1	6.46^{ab}±1.12	430.00^{b}±28.86	3.53^{bc}±33.82	43.33^{a}±3.33	30.53^{a}±1.
Parvati-2	6.26^{ab}±1.20	420.00^{b}±98.65	3.60^{bc}±75.71	60.00^{a}±20.00	33.20^{a}±4.
G-389	6.16^{ab}±68.87	396.66^{b}±86.85	3.30^{bc}±56.86	50.00^{a}±11.54	30.86^{a}±3.
G-384	6.76^{a}±1.13	473.33^{b}±63.33	3.46^{bc}±17.63	53.33^{a}±13.33	36.46^{a}±1.
G-282	5.03^{ab}±46.66	346.66^{b}±35.27	3.00^{bc}±26.45	43.33^{a}±3.33	32.60^{a}±3
G-404	4.13^{b}±26.66	360.00^{b}±45.09	2.90^{c}±32.14	43.33^{a}±6.66	40.66^{a}±2

Table 8. : Effect of different characters in garlic cultivars

Genetic Diversity- Hierarchical Clustering among cultivars

Hierarchical clustering by wards method of different garlic cultivars responding to different plant growth factors clusters Fewari in one major cluster and remaining in two other clusters. The second cluster is segregated into further sub-clusters; sub-cluster 1 in second major cluster groups G1, Parvati-2, G-189, and G-389; however the sub-cluster 2 in second major cluster groups G-323, G-282, G-384, and G-50 (**Figure 4**). Fewari cultivar responds well to the specific environment provided in the research and subsequently all the values of plant growth factors; specifically, clove weight is very much high which segregates Fewari cultivar from others.

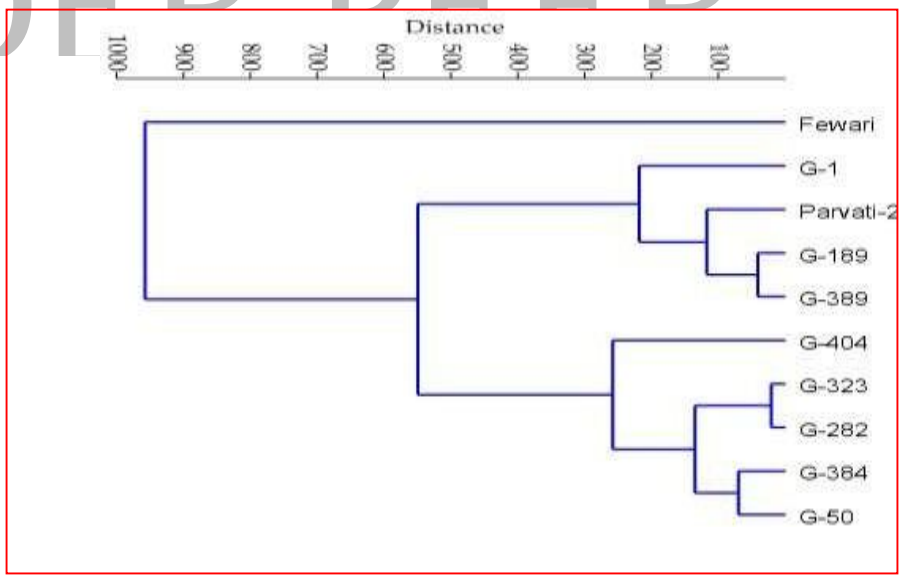
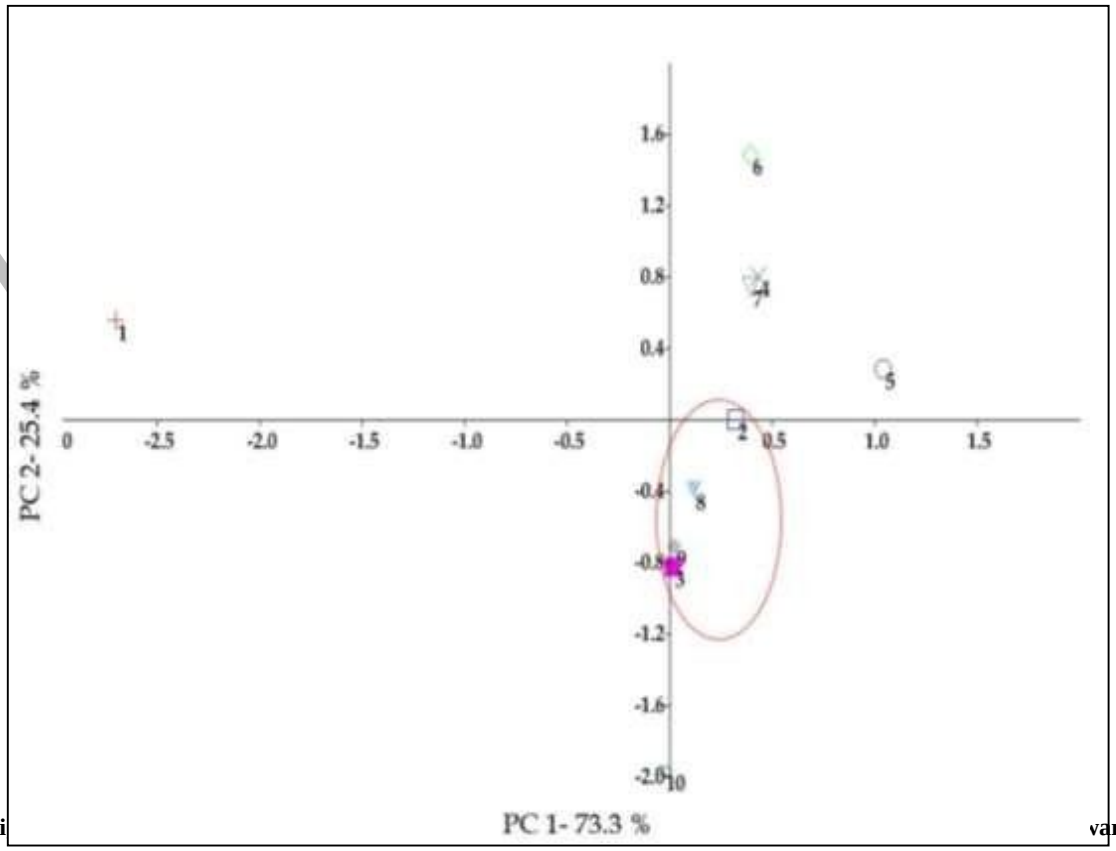


Figure 4: Hierarchical clustering (morphological characters) among different garlic cultivars

Ordination of 10 different garlic cultivators in the function of three replications in space defined by the PC1 and PC2 axis of the PCA analysis carried out with different plant growth parameters. Components 1 and 2 represent 73.3 % and 25.4 % of the variation in data respectively.

The Principal Component Analysis has been performed to evaluate the variability among different garlic cultivars. The first principal component axis (PC1) explained 73.3 % while the second principal component axis (PC2) showed 25.4 % of the variance in the data (**Figure 5**). Fewari in the PCA plot showed high variability from other cultivars; however G-323, G-282, G-384, and G-50 exhibit less variation concerning plant growth factor analysis. PCA shows a close similarity between G-389 and G-189. Further molecular studies are required to understand the genetic similarity and variability among different cultivars.



Fi **vari,2-G-50,3-G-323,4-G-189,5-G-1,6-Parvati-2,7-G-389,8-G-384,9-G-282, 10-G-404)**

Conclusion

The major objective of this study was to evaluate the response of ten different garlic cultivars popularly grown in alluvial soils of Punjab, and to identify the genetic variation among the garlic cultivars. Statistical analysis for growth and yield parameters revels high variation among the garlic cultivars grown in same environment and alluvial soil; which suggest huge opportunities to improve the breeding lines of garlic cultivars growth in the region. Hierarchical clustering based on morphological characters segregates G1, Parvati-2, G-189, and G-389 in a group and G-323, G-282, G-384 and G-50 in another group which shows the performance similarities of garlic cultivars. Principal component analysis (PCA) show the close similarity between G-389 and G-189 cultivars and Fewari cultivars show high variation as compared to all other cultivars. Molecular studies were required to more precisely calculate the genetic variations among the garlic cultivars.

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