

## **Original Research Article**

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

#### **Abstract**

A field experiment was conducted at the Agricultural farm of the Lovely Professional University, Punjab to evaluate the performance of different cultivars of garlic for growth factor and yield parameters. Ten cultivars *viz.*, Fewari, G-50, G-323, G-189, G-1, Parvati-2, G-389, G-384, G-282, and G-404 were selected for the experiment (randomized block design) with three replications. Plant height up to 30 days, days of the interval is not significant for all varieties, however, at 45, 60, 90, and 120 days of interval plant height of Parvati-2, G-389, G-389, G-189, and G189 were high whereas G-323, G-40, and Fewari found significantly lower. The Psudostem length of garlic variety showed in 30, 45, 60, 90, and 120 days of interval length is higher G-389, and the length of bulb was found significantly higher in Fewari and G-404. Bulb width was higher in Parvati-2 and low in G-404. Cloves length of garlic is higher in Fewari however G-282 and G-404 showed significantly lower lengths. The cluster analysis based on growth and yield parameters showed the major two clusters, *viz.*, Fewari in one major cluster and 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. Fewari cultivar responds well to the specific environment provided in the research and subsequently, all the values of plant growth factors as also confirmed by PCA analysis as the Fewari variety in the PCA plot showed high variability from 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 (Abraha et al., 2015). Cultivated garlic is known for at least 5000 years ago in India and Egypt; and understood to originate in

Comment [RM1]: Add background, aims, and novelty

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 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 agricultural 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 (Pervin et al., 2014). The present study evaluates the performance and variability of plant growth parameters among ten different and majorly grown garlic cultivars of 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.

**Table 1: List of Genotypes**

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



### **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 (treatments) with three replications each are grown in an RBD design plot of 14mX 6m in size and spacing of 10cm × 7cm which accommodates 40 plants per plot. During this experiment, the seasonal temperature was cold and after that moist and warm. 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.

### **Planting**

The selection of cloves is important for garlic planting. Individual cloves from seed garlic bulbs should be 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, Psudostem Length, Psudostem 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 Psudostem by scientific measuring tap, Psudostem 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

One-way ANOVA and Duncan's multiple range test (DMRT) for comparison of means were performed using software SPSS version 16. Unless otherwise stated, the level of significance referred to in the results is  $P < 0.05$ . 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

The plant height at 30 days is not significantly varied and all are at par. However, at 45 days variation has been recorded as variety Parvati-2 and G-389 showed maximum plant height (38.8a and 38.96a respectively) and the lowest value recorded for variety 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 No. 2**). 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.

**Table 2: Plant height among different cultivars in different intervals**

| Treatments    | Plant Height<br>30 DAS   | Plant Height 45<br>DAS    | Plant Height<br>60 DAS     | Plant Height<br>90 DAS   | Plant Height<br>120 DAS  |
|---------------|--------------------------|---------------------------|----------------------------|--------------------------|--------------------------|
| <b>Fewari</b> | 29.13 <sup>a</sup> ±1.05 | 37.40 <sup>ab</sup> ±1.41 | 37.32 <sup>abc</sup> ±2.14 | 40.46 <sup>b</sup> ±1.27 | 49.73 <sup>b</sup> ±1.53 |

|                  |                          |                           |                           |                          |                          |
|------------------|--------------------------|---------------------------|---------------------------|--------------------------|--------------------------|
| <b>G-50</b>      | 29.21 <sup>a</sup> ±1.35 | 35.64 <sup>ab</sup> ±0.54 | 39.53 <sup>ab</sup> ±0.67 | 51.90 <sup>a</sup> ±0.98 | 77.73 <sup>a</sup> ±5.42 |
| <b>G-323</b>     | 28.28 <sup>a</sup> ±1.50 | 30.70 <sup>c</sup> ±1.45  | 31.73 <sup>c</sup> ±2.56  | 50.50 <sup>a</sup> ±3.11 | 75.66 <sup>a</sup> ±3.20 |
| <b>G-189</b>     | 29.00 <sup>a</sup> ±0.39 | 36.46 <sup>ab</sup> ±0.65 | 38.23 <sup>ab</sup> ±2.57 | 56.45 <sup>a</sup> ±3.14 | 80.06 <sup>a</sup> ±3.17 |
| <b>G-1</b>       | 28.88 <sup>a</sup> ±1.63 | 33.76 <sup>bc</sup> ±1.53 | 35.53 <sup>bc</sup> ±0.72 | 49.16 <sup>a</sup> ±1.37 | 71.26 <sup>a</sup> ±1.33 |
| <b>Parvati-2</b> | 28.01 <sup>a</sup> ±0.49 | 38.86 <sup>a</sup> ±1.71  | 36.00 <sup>bc</sup> ±1.11 | 52.50 <sup>a</sup> ±0.87 | 77.60 <sup>a</sup> ±3.95 |
| <b>G-389</b>     | 29.28 <sup>a</sup> ±1.51 | 38.96 <sup>a</sup> ±1.89  | 42.10 <sup>a</sup> ±0.60  | 54.97 <sup>a</sup> ±4.50 | 79.13 <sup>a</sup> ±2.82 |
| <b>G-384</b>     | 27.99 <sup>a</sup> ±0.05 | 36.26 <sup>ab</sup> ±1.67 | 35.60 <sup>bc</sup> ±2.87 | 50.63 <sup>a</sup> ±4.09 | 76.86 <sup>a</sup> ±3.17 |
| <b>G-282</b>     | 28.98 <sup>a</sup> ±1.82 | 37.73 <sup>ab</sup> ±1.52 | 39.10 <sup>ab</sup> ±0.86 | 53.66 <sup>a</sup> ±2.06 | 76.73 <sup>a</sup> ±2.81 |
| <b>G-404</b>     | 27.00 <sup>a</sup> ±2.35 | 29.82 <sup>c</sup> ±0.89  | 33.86 <sup>bc</sup> ±0.43 | 50.86 <sup>a</sup> ±1.30 | 71.20 <sup>a</sup> ±2.19 |

The number of garlic leaves at 30-day variety, Fewari showed maximum 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 No. 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 3: Effects of Leaves Numbers on different days of interval**

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

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

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, except 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 5: Effects of Leaves Width on different days of interval**

| 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 |
|------------------|------------------------|------------------------|------------------------|------------------------|-------------------------|
| <b>Fewari</b>    | 0.75a±.07              | 1.50a±0.0              | 1.45a±0.06             | 2.30a±0.03             | 3.17a±0.1               |
| <b>G-50</b>      | 0.74a±.02              | 1.18abc±0              | 1.30ab±0.0             | 1.93a±0.10             | 2.02b±0.02              |
| <b>G-323</b>     | 0.72a±.05              | 1.08bc±0.1             | 1.16bc±0.0             | 1.94a±0.10             | 2.07b±0.14              |
| <b>G-189</b>     | 0.77a±.05              | 1.16bc±0.1             | 1.32ab±0.05            | 2.16a±0.06             | 1.98b±0.25              |
| <b>G-1</b>       | 0.78a±.00              | 1.24ab±0.1             | 1.22bc±0.0             | 1.92a±0.04             | 2.03b±0.08              |
| <b>Parvati-2</b> | 0.78a±.03              | 1.25ab±0.0             | 1.22bc±0.0             | 2.00a±0.00             | 2.07b±0.13              |
| <b>G-389</b>     | 0.72a±.06              | 1.25ab±0.0             | 1.31ab±0.0             | 2.02a±0.02             | 1.83b±0.27              |
| <b>G-384</b>     | 0.78a±.04              | 1.25ab±0.1             | 1.29ab±0.0             | 1.79a±0.12             | 1.63b±0.05              |
| <b>G-282</b>     | 0.73a±.01              | 1.32ab±0.1             | 1.34ab±0.0             | 2.00a±0.13             | 1.73b±0.09              |
| <b>G-404</b>     | 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 Pseudostem lengths was recorded for G-389, G-50, G-323 (17.63bc) and lower pseudo stem length was for Fewari found lowest. All variety variables but not significant Pseudostem length are shown in **Table No. 6**. The results observed are in accordance with **Abhilash et al., 2014; Azuara et al., 2008**; where they reported that the Pseudostem length was found higher for G-389, G-50, and G-323 variety and lower for Fewari.

**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 |
|------------------|-----------------------------|-----------------------------|-----------------------------|-----------------------------|------------------------------|
| <b>Fewari</b>    | 2.46 <sup>c</sup> ±0.46     | 3.33 <sup>d</sup> ±0.52     | 4.72 <sup>d</sup> ±0.83     | 6.33 <sup>d</sup> ±0.98     | 10.00 <sup>c</sup> ±0.52     |
| <b>G-50</b>      | 8.00 <sup>b</sup> ±1.40     | 11.40 <sup>bc</sup> ±1.30   | 15.26 <sup>bc</sup> ±2.75   | 17.26 <sup>bc</sup> ±2.02   | 28.53 <sup>ab</sup> ±0.56    |
| <b>G-323</b>     | 7.43 <sup>b</sup> ±0.85     | 9.80 <sup>c</sup> ±0.60     | 13.80 <sup>c</sup> ±0.60    | 17.63 <sup>bc</sup> ±1.12   | 26.26 <sup>ab</sup> ±1.37    |
| <b>G-189</b>     | 7.70 <sup>b</sup> ±2.82     | 9.83 <sup>c</sup> ±3.00     | 16.13 <sup>bc</sup> ±1.31   | 19.06 <sup>b</sup> ±0.75    | 28.13 <sup>ab</sup> ±3.13    |
| <b>G-1</b>       | 7.00 <sup>b</sup> ±0.70     | 9.50 <sup>c</sup> ±0.26     | 12.13 <sup>c</sup> ±0.63    | 14.53 <sup>c</sup> ±1.15    | 26.80 <sup>ab</sup> ±0.61    |
| <b>Parvati-2</b> | 9.00 <sup>b</sup> ±0.94     | 12.06 <sup>bc</sup> ±0.98   | 14.93 <sup>bc</sup> ±0.88   | 18.80 <sup>b</sup> ±0.80    | 30.33 <sup>a</sup> ±2.24     |
| <b>G-389</b>     | 14.13 <sup>a</sup> ±1.67    | 18.53 <sup>a</sup> ±2.03    | 22.26 <sup>a</sup> ±1.22    | 25.53 <sup>a</sup> ±1.45    | 31.66 <sup>a</sup> ±2.20     |
| <b>G-384</b>     | 10.93 <sup>ab</sup> ±1.07   | 14.13 <sup>b</sup> ±0.24    | 18.36 <sup>b</sup> ±1.02    | 20.00 <sup>b</sup> ±0.70    | 30.60 <sup>a</sup> ±2.25     |
| <b>G-282</b>     | 9.66 <sup>b</sup> ±0.26     | 12.40 <sup>bc</sup> ±0.30   | 15.26 <sup>bc</sup> ±0.86   | 18.33 <sup>b</sup> ±0.69    | 27.20 <sup>ab</sup> ±1.66    |
| <b>G-404</b>     | 7.80 <sup>b</sup> ±0.30     | 10.20 <sup>bc</sup> ±0.30   | 13.46 <sup>c</sup> ±0.26    | 16.86 <sup>bc</sup> ±0.24   | 24.33 <sup>b</sup> ±0.29     |

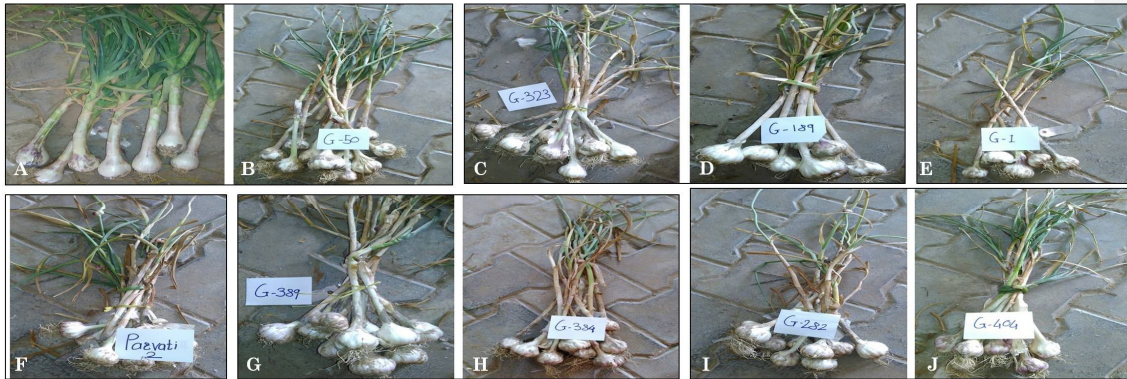
At the 30 days, the Pseudostem diameter for G-282 variety was found significantly higher and lower for G-404 variety. However, at 45 days interval, the Pseudostem diameter not varied for all varieties and the trend changes at 60-days interval where the variety G-389 found higher pseudostem diameter. At 90 days intervals, Pseudostem diameter was found maximum for variety G-50 and found minimum for Parvati-2 variety. At 120 days of the interval, the Pseudostem 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 No.7**. Similar studies by **Rakesh, 2016; Panthee et al.,2006; Batth et al 2013;** reported the higher Pseudostem diameter for

variety G-282, G-189, G-50, and Fewari and the lower Pseudostem diameter for variety G-404, Parvati-2.

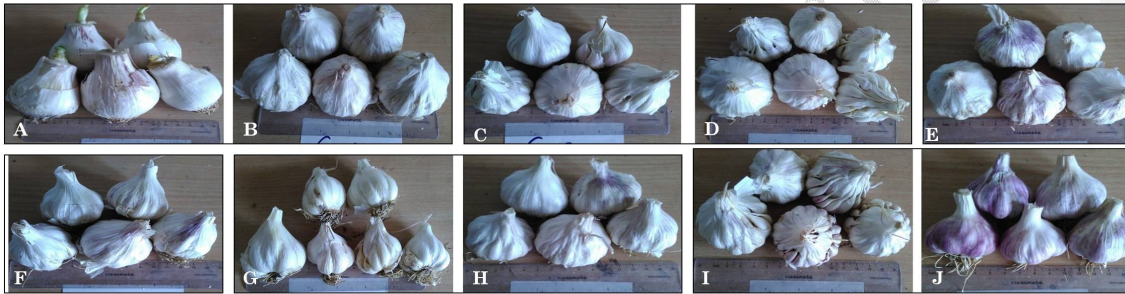
**Table 7: Effect of Pseudostem Diameter on different days of interval**

| 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 |
|------------------|-------------------------------|-------------------------------|-------------------------------|-------------------------------|--------------------------------|
| <b>Fewari</b>    | 0.60 <sup>a</sup> ±0.02       | 0.84 <sup>ab</sup> ±0.02      | 1.14 <sup>ab</sup> ±0.09      | 1.39 <sup>b</sup> ±0.09       | 1.74 <sup>a</sup> ±0.10        |
| <b>G-50</b>      | 0.62 <sup>a</sup> ±0.04       | 0.83 <sup>ab</sup> ±0.04      | 1.15 <sup>ab</sup> ±0.06      | 2.20 <sup>a</sup> ±0.70       | 1.52 <sup>ab</sup> ±0.04       |
| <b>G-323</b>     | 0.55 <sup>a</sup> ±0.07       | 0.81 <sup>ab</sup> ±0.05      | 1.11 <sup>ab</sup> ±0.04      | 1.38 <sup>b</sup> ±0.04       | 1.48 <sup>ab</sup> ±0.08       |
| <b>G-189</b>     | 0.55 <sup>a</sup> ±0.10       | 0.84 <sup>ab</sup> ±0.05      | 1.24 <sup>a</sup> ±0.06       | 1.56 <sup>ab</sup> ±0.07      | 1.60 <sup>ab</sup> ±0.10       |
| <b>G-1</b>       | 0.86 <sup>a</sup> ±0.33       | 0.81 <sup>ab</sup> ±0.02      | 1.11 <sup>ab</sup> ±0.02      | 1.31 <sup>b</sup> ±0.03       | 1.50 <sup>ab</sup> ±0.05       |
| <b>Parvati-2</b> | 0.60 <sup>a</sup> ±0.02       | 0.79 <sup>ab</sup> ±0.02      | 1.01 <sup>b</sup> ±0.02       | 1.20 <sup>b</sup> ±0.02       | 1.46 <sup>ab</sup> ±0.16       |
| <b>G-389</b>     | 0.99 <sup>a</sup> ±0.46       | 0.80 <sup>ab</sup> ±0.01      | 1.14 <sup>ab</sup> ±0.02      | 1.38 <sup>b</sup> ±0.01       | 1.40 <sup>bc</sup> ±0.06       |
| <b>G-384</b>     | 0.88 <sup>a</sup> ±0.20       | 0.85 <sup>ab</sup> ±0.01      | 1.15 <sup>ab</sup> ±0.01      | 1.35 <sup>b</sup> ±0.01       | 1.42 <sup>bc</sup> ±0.04       |
| <b>G-282</b>     | 1.00 <sup>a</sup> ±0.43       | 0.86 <sup>a</sup> ±0.04       | 1.22 <sup>a</sup> ±0.02       | 1.46 <sup>b</sup> ±0.03       | 1.38 <sup>bc</sup> ±0.04       |
| <b>G-404</b>     | 0.52 <sup>a</sup> ±0.07       | 0.72 <sup>b</sup> ±0.06       | 1.02 <sup>b</sup> ±0.04       | 1.21 <sup>b</sup> ±0.07       | 1.16 <sup>c</sup> ±0.05        |

The length of the bulb was found highest for Fewari variety and the lowest for G-404 variety (5.14a and 3.52c). The clove length of garlic was recorded highest for Fewari variety and lowest cloves length observed in G-282 and G-404 (5.14a, 2.44c, and 2.40c) (Table 8). The clove's width of garlic was found significantly higher for the Fewari variety and the lowest width observed for variety G-282 and G-1 varieties (5.26a and 0.85c) 1 cloves weight for Fewari variety shown more cloves weight and G-404 recorded less cloves weight (42.73a and 1.58b). Studies by **Abhilash et al., 2014; Gayle 2009; Hazem 2013**; confirms that garlic morphological parameters specially bulb



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



Bulbs 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

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**Table 8: Effect of different characters in garlic cultivars**

| <b>Treat-ments</b> | <b>Length of Bulbs</b>   | <b>Bulb Width</b>      | <b>Cloves Length</b>     | <b>Cloves Width</b>     | <b>1 Cloves Weight</b>   | <b>Total no. of Cloves</b> |
|--------------------|--------------------------|------------------------|--------------------------|-------------------------|--------------------------|----------------------------|
| <b>Fewari</b>      | 5.14 <sup>a</sup> ±0.00  | 5.26 <sup>a</sup> ±0.0 | 5.14 <sup>a</sup> ±0.04  | 5.26 <sup>a</sup> ±0.00 | 42.73 <sup>a</sup> ±0.86 | 11.40 <sup>e</sup> ±0.11   |
| <b>G-50</b>        | 3.91 <sup>bc</sup> ±0.15 | 5.08 <sup>a</sup> ±0.1 | 2.89 <sup>bc</sup> ±0.12 | 0.93 <sup>c</sup> ±0.07 | 2.32 <sup>b</sup> ±0.19  | 45.53 <sup>abc</sup> ±2.7  |
| <b>G-323</b>       | 3.66 <sup>bc</sup> ±0.17 | 4.64 <sup>a</sup> ±0.2 | 2.78 <sup>bc</sup> ±0.20 | 0.92 <sup>c</sup> ±0.02 | 2.31 <sup>b</sup> ±0.53  | 37.13 <sup>bcd</sup> ±4.7  |
| <b>G-189</b>       | 3.90 <sup>bc</sup> ±0.15 | 4.79 <sup>a</sup> ±0.2 | 2.58 <sup>bc</sup> ±0.16 | 0.86 <sup>c</sup> ±0.07 | 1.84 <sup>b</sup> ±0.40  | 48.60 <sup>a</sup> ±5.71   |
| <b>G-1</b>         | 3.70 <sup>bc</sup> ±0.12 | 4.74 <sup>a</sup> ±0.1 | 2.74 <sup>bc</sup> ±0.12 | 0.85 <sup>c</sup> ±0.02 | 2.05 <sup>b</sup> ±0.20  | 49.26 <sup>a</sup> ±2.77   |
| <b>Parvati-2</b>   | 3.85 <sup>bc</sup> ±0.19 | 7.81 <sup>a</sup> ±3.3 | 2.80 <sup>bc</sup> ±0.06 | 0.93 <sup>c</sup> ±0.04 | 1.92 <sup>b</sup> ±0.37  | 36.26 <sup>cd</sup> ±2.6   |
| <b>G-389</b>       | 4.14 <sup>b</sup> ±0.06  | 7.65 <sup>a</sup> ±3.1 | 2.98 <sup>b</sup> ±0.17  | 1.02 <sup>c</sup> ±0.05 | 2.64 <sup>b</sup> ±0.37  | 30.00 <sup>d</sup> ±4.20   |
| <b>G-384</b>       | 3.84 <sup>bc</sup> ±0.12 | 4.84 <sup>a</sup> ±0.0 | 3.06 <sup>b</sup> ±0.23  | 0.90 <sup>c</sup> ±0.01 | 2.60 <sup>b</sup> ±0.22  | 38.40 <sup>abcd</sup> ±0.6 |
| <b>G-282</b>       | 3.54 <sup>c</sup> ±0.22  | 4.39 <sup>a</sup> ±0.2 | 2.44 <sup>c</sup> ±0.11  | 0.85 <sup>c</sup> ±0.02 | 1.67 <sup>b</sup> ±0.06  | 35.33 <sup>cd</sup> ±3.6   |
| <b>G-404</b>       | 3.52 <sup>c</sup> ±0.07  | 3.71 <sup>a</sup> ±0.0 | 2.40 <sup>c</sup> ±0.09  | 1.27 <sup>b</sup> ±0.10 | 1.58 <sup>b</sup> ±0.04  | 27.13 <sup>d</sup> ±0.99   |

The whole plant weight taken after harvesting the garlic crop; the G-384 variety has more weight and Fewari recorded significantly less weight (6.76a and 1.52c). The dry weight taken after 10 days recorded highest for G-50 variety and the lowest for Fewari variety (7.40a and 1.52c). The

bulb weight recorded high for Fewari and low for Parvati-2 variety. Genetic performance analysis studies by **Abhilash** et al., 2014; Cardellina 2013; Esho 2015 report that the morphological parameter of garlic precisely whole plant weight were found higher in G-384 and lower weight for Fewari. (**Table 9**). The bulbils color after flowering for G-189, G-1, G-384, and G-282 was found Pink whereas bulbils color for variety G-323, Parvati-2, and G-404 was found white.

**Table 9. : Effect of different characters in garlic cultivars**

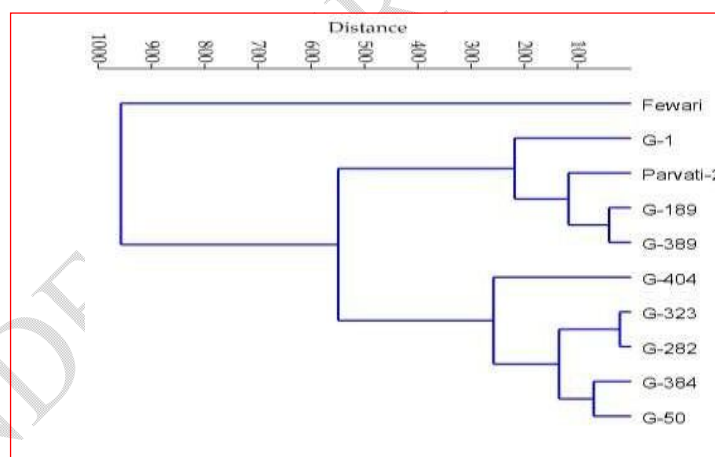
| Treat-ments      | 10 Bulb with Leaves Weight | 10 Dry Bulb Weight         | 10 Bulb Weight            | 1 Bulb Weight             | Total No. Plants/plot    |
|------------------|----------------------------|----------------------------|---------------------------|---------------------------|--------------------------|
| <b>Fewari</b>    | 1.52 <sup>c</sup> ±0.07    | 780.00 <sup>a</sup> ±15.27 | 6.50 <sup>a</sup> ±28.86  | 60.00 <sup>a</sup> ±5.77  | 33.40 <sup>a</sup> ±1.70 |
| <b>G-50</b>      | 7.40 <sup>a</sup> ±32.14   | 486.66 <sup>b</sup> ±36.66 | 4.36 <sup>b</sup> ±34.80  | 41.66 <sup>a</sup> ±18.33 | 31.46 <sup>a</sup> ±2.66 |
| <b>G-323</b>     | 5.33 <sup>ab</sup> ±12.01  | 373.33 <sup>b</sup> ±29.05 | 3.06 <sup>bc</sup> ±20.27 | 43.33 <sup>a</sup> ±3.33  | 37.26 <sup>a</sup> ±1.68 |
| <b>G-189</b>     | 5.86 <sup>ab</sup> ±98.20  | 426.66 <sup>b</sup> ±86.85 | 3.23 <sup>bc</sup> ±47.02 | 43.33 <sup>a</sup> ±6.66  | 29.73 <sup>a</sup> ±5.95 |
| <b>G-1</b>       | 6.46 <sup>ab</sup> ±1.12   | 430.00 <sup>b</sup> ±28.86 | 3.53 <sup>bc</sup> ±33.82 | 43.33 <sup>a</sup> ±3.33  | 30.53 <sup>a</sup> ±1.57 |
| <b>Parvati-2</b> | 6.26 <sup>ab</sup> ±1.20   | 420.00 <sup>b</sup> ±98.65 | 3.60 <sup>bc</sup> ±75.71 | 60.00 <sup>a</sup> ±20.00 | 33.20 <sup>a</sup> ±4.50 |
| <b>G-389</b>     | 6.16 <sup>ab</sup> ±68.87  | 396.66 <sup>b</sup> ±86.85 | 3.30 <sup>bc</sup> ±56.86 | 50.00 <sup>a</sup> ±11.54 | 30.86 <sup>a</sup> ±3.23 |
| <b>G-384</b>     | 6.76 <sup>a</sup> ±1.13    | 473.33 <sup>b</sup> ±63.33 | 3.46 <sup>bc</sup> ±17.63 | 53.33 <sup>a</sup> ±13.33 | 36.46 <sup>a</sup> ±1.93 |
| <b>G-282</b>     | 5.03 <sup>ab</sup> ±46.66  | 346.66 <sup>b</sup> ±35.27 | 3.00 <sup>bc</sup> ±26.45 | 43.33 <sup>a</sup> ±3.33  | 32.60 <sup>a</sup> ±3.7  |

G-404 4.13<sup>b</sup>±26.66 360.00<sup>b</sup>±45.09 2.90<sup>c</sup>±32.14 43.33<sup>a</sup>±6.66 40.66<sup>a</sup>±2.7

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### 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. 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 3:** 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). 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.

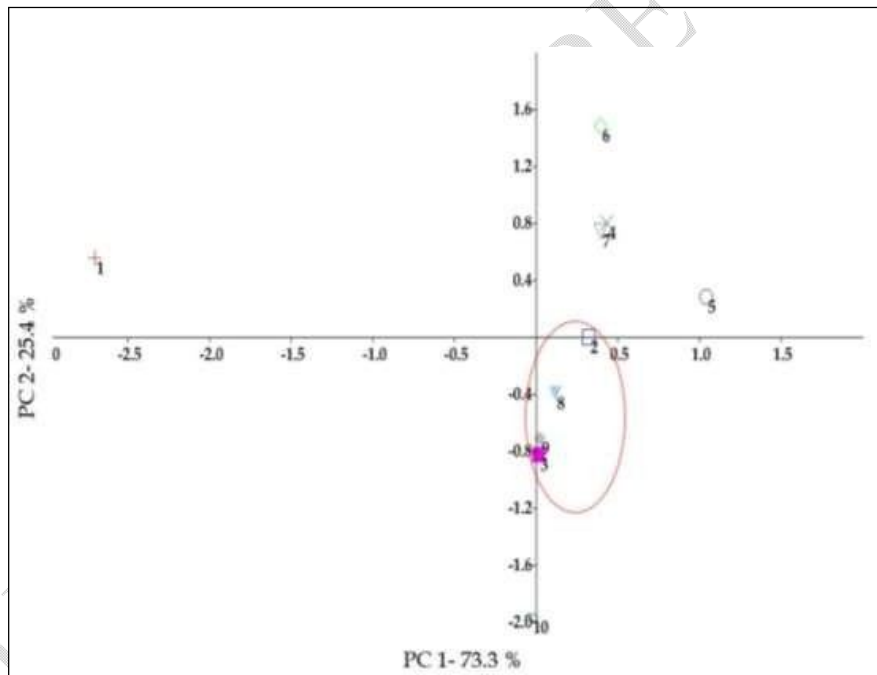


Figure 4: Variation Analysis of different cultivars of Garlic by principal components analysis (PCA): (1-Fewari, 2- G-50, 3- G-323, 4- G-189, 5- G-1, 6- Parvati-2, 7- G-389, 8- G-384, 9- G-282, 10- G-404)

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