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Evaluation of okra (*Abelmoschus esculentus* L. Moench) cultivars for growth, yield, biochemical traits and resistance to *Earias vittella* under field conditions

A R Japda[1*], J S Patel[2], P K Ukani[3], G D Guna[4], H R Sodhaparmar[5], J M Khaniya[6], J J Dhruve[7]
[1]Agriculture Officer, Department of Biochemistry, CoA, JAU, Junagadh, Gujarat, India
[2] Associate Professor, Department of Biochemistry, CoA, AAU, Anand, Gujarat, India
[3] Assistant Professor, College of Agriculture, AAU, Jabugam, Gujarat, India
[4] Department of Biochemistry, CoA, JAU, Junagadh, Gujarat, India
[5] Assistant Professor, Department of Biochemistry, CoA, JAU, Junagadh, Gujarat, India
[6] Assistant Professor, Department of Biotechnology, CoA, JAU, Junagadh, Gujarat, India
[7] Professor and Head, Department of Biotechnology, CoA, AAU, Gujarat, India
Corresponding Author: A R Japda
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Abstract
Okra (*Abelmoschus esculentus* L. Moench) is an economically important vegetable crop valued for its nutritional, medicinal and commercial significance. The present investigation was conducted to evaluate the performance of ten okra cultivars for growth, yield, biochemical attributes and resistance to the fruit and shoot borer (*Earias vittella*) under the agro-climatic conditions of Anand, Gujarat, India. Significant variability was observed among the cultivars for all the studied traits. Cultivar GAO-5 exhibited superior agronomic performance by recording the maximum plant height (101.87 cm), fruit length (13.70 cm), fruit girth (2.83 cm), fruit weight (12.37 g), fruit volume (9.28 cm^3) and fruit yield (85.89 q ha^{-1}). GAO-5 also showed the lowest incidence of *Earias vittella*, with minimum shoot and fruit damage at both 35 and 60 days after sowing, indicating greater tolerance to fruit and shoot borer infestation. Biochemical analysis revealed considerable variation among the cultivars. GAO-5 recorded the highest carbohydrate content (9.03%), mucilage content (246 mg 100 g^{-1}), total phenols (0.086%), antioxidant activity (0.49%), ascorbic acid (39.66 mg 100 g^{-1}) and total chlorophyll content (1.51 mg g^{-1}), whereas Glory possessed the highest moisture and sugar contents. Nirmala-303 exhibited the highest true protein content, while GO-2 recorded the highest chlorophyll *b* and carotenoid contents. GAO-5 emerged as the most promising cultivar for commercial cultivation and as a valuable genetic resource for future breeding programmes aimed at improving productivity, quality and insect resistance in okra.

Keywords: *Abelmoschus esculentus*, okra, cultivar evaluation, *Earias vittella*, biochemical traits, antioxidant activity, yield, genetic variability

Introduction
Okra (*Abelmoschus esculentus* L. Moench), commonly known as lady's finger, is one of the most important vegetable crops belonging to the family Malvaceae. It is cultivated extensively in tropical and subtropical regions of the world due to its adaptability to diverse environmental conditions and its high economic value (Benchasri, 2012) [3]. The crop is believed to have originated in Ethiopia and was subsequently distributed throughout Africa, Asia, the Mediterranean region and the Americas (Kumar *et al.,* 2010) [16].

Okra pods are highly nutritious and constitute an important source of vitamins, minerals, dietary fiber and bioactive compounds. Fresh pods contain significant amounts of vitamins A, C and K, calcium, potassium and folate, making them valuable for human nutrition (Gemede *et al.*, 2015) [10]. The crop is also recognized for its medicinal properties, as its mucilage and phytochemical constituents exhibit antioxidant, antidiabetic, antimicrobial and anti-inflammatory activities (Gemede *et al.,* 2015) [10].

India is the leading producer of okra globally, accounting for a major share of world production. The crop is cultivated throughout the year under varying agro-climatic conditions and contributes significantly to the income of small and marginal farmers (FAOSTAT, 2024). Despite its importance, okra productivity is often limited by various biotic stresses such as insect pests and diseases, as well as abiotic stresses including drought, salinity and high temperature conditions (Dhankhar and Mishra, 2005) [7].

The increasing demand for nutritious vegetables and the challenges posed by climate change have intensified the need for research aimed at improving okra productivity, quality and stress tolerance. Therefore, studies focusing on crop improvement, nutrient management, disease resistance and sustainable cultivation practices are essential to ensure enhanced production and food security. Understanding the biological, agronomic and nutritional aspects of okra can contribute significantly to the development of improved cultivation strategies and high-performing cultivars.

Materials and methods
The present investigation was conducted at the Main Vegetable Research Station and the laboratory analyses were carried out in the Department of Biochemistry and the Department of Agricultural Biotechnology, B. A. College of Agriculture, Anand Agricultural University, Anand, Gujarat,

India. The experimental material comprised ten cultivars of okra (*Abelmoschus esculentus* L. Moench), namely Ankur-40, Arka Anamika, GAO-5, GO-2, Ganesh, Glory, Jyoti, Nirmala-303, Parbhani Kranti and Shive. These cultivars were selected to evaluate their performance and variability under the agro-climatic conditions of Anand.

Experimental Design and Layout

The experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications. The experimental field was divided into three blocks, each representing one replication. Each replication was further subdivided into ten plots, corresponding to the ten okra cultivars under study. The cultivars were randomly assigned to the plots within each replication to minimize environmental variation and ensure unbiased estimation of treatment effects.

Standard agronomic practices recommended for okra cultivation were followed uniformly for all the experimental plots throughout the crop growth period. Observations were recorded from representative plants selected from each plot for further analysis.

Growth and Yield Attributes

1. **Plant height at harvest (cm)**
   Plant height was recorded from the base of the stem to the apex of the main shoot in five randomly selected plants from each plot at harvest. The average value was expressed in centimeters (cm).

2. **Fruit length (cm)**
   Five fruits were randomly selected from each sampled plant and fruit length was measured using a vernier caliper. The mean value was expressed in centimeters (cm).

3. **Fruit diameter (cm)**
   Fruit diameter was measured on five randomly selected fruits from each sampled plant using a vernier caliper and expressed in centimeters (cm).

4. **Fruit weight (g)**
   Five randomly selected fruits from each sampled plant were weighed using an electronic balance and the average fruit weight was recorded in grams (g).

5. **Fruit volume (cm^3)**
   Fruit volume was determined by the water displacement method using five randomly selected fruits. The displaced water volume was recorded and expressed in cubic centimeters (cm^3).

6. **Fruit density (g/cm^3)**
   Fruit density was calculated as the ratio of fruit weight to fruit volume using the following formula:

Fruit Density (g/cm^3) = Fruit Weight (g) / Fruit Volume (cm^3)

7. **Fruit Yield (q/ha)**

The total fruit yield per plant and per plot was recorded and subsequently converted into yield per hectare, expressed in quintals per hectare (q/ha).

Pest Damage Status

1. **Number of larvae of fruit borers**

Larvae of fruit borer were counted on fruit by visual observation on the randomly selected five plants.

2. **Number of fruit and shoot borers**

Larvae of fruit and shoot borer were counted on fruit by visual observation on the randomly selected five plants.

Biochemical Parameters

1. **Moisture Content:** Moisture was determined by drying 5 g fresh fruit samples at 105°C for 5 h in a hot air oven and calculating weight loss according to AOAC (2000).

2. **Mucilage Content:** Mucilage was extracted from homogenized fruit samples using water, precipitated with ethanol, washed with ethanol and acetone, vacuum-dried and weighed (Woolfe *et al.,* 1976).

3. **Crude Fibre Content:** Fibre was estimated following Maynard (1970) [22]. Defatted samples were sequentially digested with sulfuric acid and sodium hydroxide, dried, ignited and crude fibre percentage was calculated from weight differences.

4. **Total Carbohydrates:** Total carbohydrates were estimated by the phenol-sulfuric acid method of Dubois *et al.* (1956). Acid-hydrolyzed extracts were reacted with phenol and concentrated sulfuric acid and absorbance was recorded at 490 nm.

5. **Total Soluble Sugars:** Methanolic extracts were analyzed using the phenol-sulfuric acid method and absorbance was measured at 490 nm using D-glucose as the standard (Dubois *et al.* (1956).

6. **Reducing Sugars:** Reducing sugars were estimated according to Somogyi (1944) [27] using alkaline copper and arsenomolybdate reagents. Absorbance was measured at 540 nm and quantified using a glucose standard curve.

7. **Total Phenols:** Total phenolic content was determined by the Folin–Ciocalteu method (Bray and Thorpe, 1954) [6]. Absorbance was measured at 650 nm using catechol as the standard.

8. **True Protein:** Protein content was estimated by the Lowry method (Lowry *et al.*, 1951) [17]. Extracts were reacted with alkaline copper reagent and Folin–Ciocalteu reagent and absorbance was recorded at 750 nm using bovine serum albumin as the standard.

9. **Total Antioxidant Activity:** Antioxidant activity was determined using the FRAP assay. Methanolic extracts were mixed with FRAP reagent, incubated for 10 min and absorbance was measured at 593 nm (Benzie and Strain (1996) [4].

10. **Ascorbic Acid:** Ascorbic acid content was estimated by the DNPH method (Bhatnagar *et al*., 2007) [5]. Extracts prepared in 3% TCA were reacted with DNPH and thiourea, followed by sulfuric acid treatment and absorbance was recorded at 540 nm.

11. **Chlorophyll Content:** Chlorophyll was estimated using the DMSO extraction method of Hiscox and Israelstam (1979) [12]. Absorbance was measured at 645 and 663 nm and chlorophyll a, b and total chlorophyll were calculated using standard equations.

12. **Carotenoids:** Carotenoid content was determined according to Nagata and Yamashita (1992) [24] using acetone (4:6) extracts. Absorbance was measured at 453, 505, 645 and 663 nm.

Enzyme Assays

1. **Peroxidase (POX):** Enzyme extracts prepared in phosphate buffer containing PVP were assayed by monitoring the increase in absorbance at 460 nm in the presence of hydrogen peroxide substrate (Guibault, 1976).

2. **Polyphenol Oxidase (PPO):** PPO activity was measured using catechol as substrate and recording the increase in absorbance at 490 nm (Malik and Singh, 1980) [20].

3. **Catalase (CAT):** Catalase activity was estimated from enzyme extracts prepared in phosphate buffer and expressed as change in absorbance per minute per gram fresh tissue (Luck, 1974) [18].

Results and discussion

Significant variation was observed among the okra cultivars for growth, fruit traits and yield parameters (Table 4.1; Fig. 4.1 and 4.2). The highest plant height was recorded in GAO-5 (101.87 cm), while the lowest was observed in Glory (76.52 cm). Similar varietal differences in plant height have been reported by Rahman *et al.* (2012) and Muhammad *et al.* (2012) [23, 26]. GAO-5 also produced the longest fruits (13.70 cm), maximum fruit girth (2.83 cm) and highest fruit weight (12.37 g), whereas Glory recorded the lowest values for these traits. The superior fruit size and weight of GAO-5 may be attributed to its better genetic potential for growth and fruit development. Similar findings were reported by Kabir and Pillu (2011) [14].

Fruit volume ranged from 7.41 to 9.28 cm^3, with the highest value recorded in GAO-5 and the lowest in Glory. Fruit density was maximum in GO-2 (1.44 g/cm^3) and minimum in Shive (1.20 g/cm^3), indicating differences in fruit compactness among cultivars. Comparable observations were reported by Ikrang (2014) [13]. Fruit yield varied significantly from 72.43 to 85.89 q/ha. The highest yield was obtained from GAO-5 (85.89 q/ha), followed by GO-2 (84.41 q/ha) and Nirmala-303 (84.19 q/ha), while Glory recorded the lowest yield (72.43 q/ha). The higher yield of GAO-5 could be attributed to its superior growth, larger fruit size and greater fruit weight. Similar varietal differences in yield were reported by Mandal *et al.* (2006) and Maity and Tripathi (2009) [19, 21]. Overall, GAO-5 proved to be the best-performing cultivar for most growth, fruit quality and yield parameters under the experimental conditions.

The incidence of *Earias vittella* varied significantly among the evaluated okra cultivars, indicating differences in their susceptibility to fruit and shoot borer infestation. At 35 DAS, cultivar GAO-5 recorded the lowest shoot and fruit damage (1.50%), which was statistically at par with Nirmala-303 (1.58%) and GO-2 (2.93%). Similarly, at 60 DAS, GAO-5 exhibited the minimum fruit damage (2.14%), followed by Nirmala-303 (2.26%) and GO-2 (4.18%), demonstrating their comparatively higher tolerance to *E. vittella*. In contrast, cultivars Glory, Arka Anamika, Ganesh and Ankur-40 showed higher levels of infestation and were categorized as susceptible.

The observed variation among cultivars is consistent with earlier reports by Vyas and Patel (1991), Aziz *et al.* (2012) and Mandal *et al.* (2006) [2, 21, 28], who also documented significant differences in susceptibility of okra cultivars to *E. vittella*. The relatively lower infestation in GAO-5 may be attributed to its lower moisture content (73.55%) and higher fibre content (1.067 mg g^{-1}), which possibly imparted tolerance against fruit and shoot borer attack.

The biochemical analysis of different okra cultivars revealed significant variation among the studied genotypes. Moisture content ranged from 73.55% to 89.66%, with Glory recording the highest moisture content, followed by Arka Anamika, whereas GAO-5 had the lowest. Conversely, GAO-5 exhibited the highest carbohydrate (9.03%) and mucilage (246 mg/100 g) contents, indicating its superior nutritional and functional quality. Similar trends for moisture and mucilage have been reported by Bangar and Patel (2012) and Woolfe *et al.* (1977) [25, 29], respectively.

Total soluble, reducing and non-reducing sugars were highest in Glory, while GAO-5 recorded the lowest sugar content. In contrast, GAO-5 possessed the highest total phenol content (0.086%), antioxidant activity (0.49%), ascorbic acid (39.66 mg/100 g, at par with Nirmala-303) and total chlorophyll (1.51 mg/g), suggesting enhanced antioxidant potential and photosynthetic pigment concentration. These findings are in agreement with previous reports by Khomsug *et al.* (2010) Bangar and Patel (2012) [15, 25].

Among the cultivars, Nirmala-303 recorded the highest true protein content (1.97%), followed by Arka Anamika**,** whereas Ankur-40 had the lowest protein content. GAO-5 also exhibited the highest chlorophyll *a* content, while GO-2 recorded the highest chlorophyll *b* and total carotenoids. The highest chlorophyll a/b ratio was observed in Glory**,** indicating differences in pigment composition among cultivars.

Overall, the results demonstrated considerable genetic variability in biochemical traits among the evaluated okra cultivars. GAO-5 emerged as the most promising genotype due to its superior carbohydrate, mucilage, phenolic content, antioxidant activity, ascorbic acid and chlorophyll content, whereas Glory was characterized by higher moisture and sugar content. These findings indicate that cultivar selection can be effectively targeted based on the desired nutritional and quality attributes for breeding and commercial cultivation.

Conclusion

The present investigation revealed significant genetic variability among the evaluated okra cultivars with respect to growth, yield, resistance to *Earias vittella* and biochemical characteristics. Among the tested cultivars, GAO-5 consistently exhibited superior performance by recording the highest plant height, fruit length, fruit girth, fruit weight, fruit volume and marketable yield. The enhanced yield potential of GAO-5 was associated with its

vigorous growth and favorable fruit characteristics, highlighting its suitability for commercial cultivation.

The incidence of *Earias vittella* differed significantly among cultivars, with GAO-5 showing the lowest shoot and fruit infestation throughout the crop growth period, followed closely by Nirmala-303 and GO-2. The comparatively lower pest incidence in GAO-5 may be attributed to its lower moisture content and higher fibre content, which possibly contributed to greater tolerance against fruit and shoot borer infestation.

Considerable variation was also observed in biochemical constituents among the cultivars. GAO-5 recorded the highest carbohydrate, mucilage, total phenol, antioxidant activity, ascorbic acid and chlorophyll content, indicating its superior nutritional and functional quality. In contrast, Glory was characterized by higher moisture and total sugar content, while Nirmala-303 exhibited the highest true protein content. These differences reflect the diverse genetic potential of the cultivars for quality related traits.

Overall, the findings demonstrate that GAO-5 is the most promising cultivar owing to its superior agronomic performance, higher yield, enhanced biochemical quality and comparatively greater tolerance to *Earias vittella*. Therefore, GAO-5 can be recommended for commercial cultivation under the experimental conditions and may serve as a valuable genetic resource for future breeding programmes aimed at improving yield, nutritional quality and insect resistance in okra.

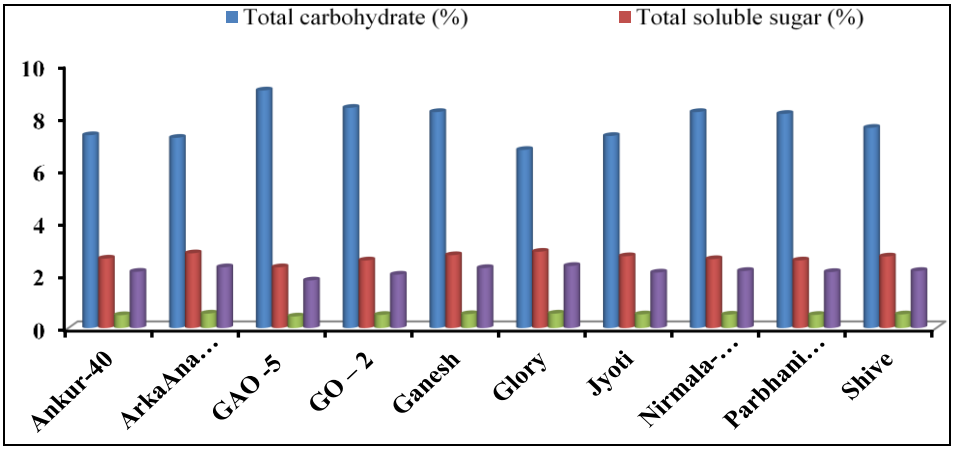

Fig 3: Total carbohydrate, total soluble sugar, reducing sugar and non reducing sugar of different cultivars of okra

Table 4: Phenol, true protein, antioxidant activity and ascorbic acid of different cultivars from okra fruits

Cultivar	Phenol (%)	True protein (%)	Antioxidant activity (%)	Ascorbic acid (mg/100g)
Ankur-40	0.069	1.64	0.41	33.58
Arka Anamika	0.059	1.94	0.36	32.69
GAO -5	0.086	1.78	0.49	39.66
GO – 2	0.083	1.73	0.47	39.04
Ganesh	0.064	1.92	0.38	34.57
Glory	0.055	1.92	0.40	36.44
Jyoti	0.075	1.85	0.47	37.12
Nirmala-303	0.082	1.97	0.44	39.66
Parbhani Kranti	0.082	1.86	0.40	37.12
Shive	0.067	1.92	0.35	39.04
S.Em.±	0.003	0.04	0.03	2.68
C.D.@5%	0.009	0.11	0.08	7.96
CV%	7.645	3.41	10.97	12.58

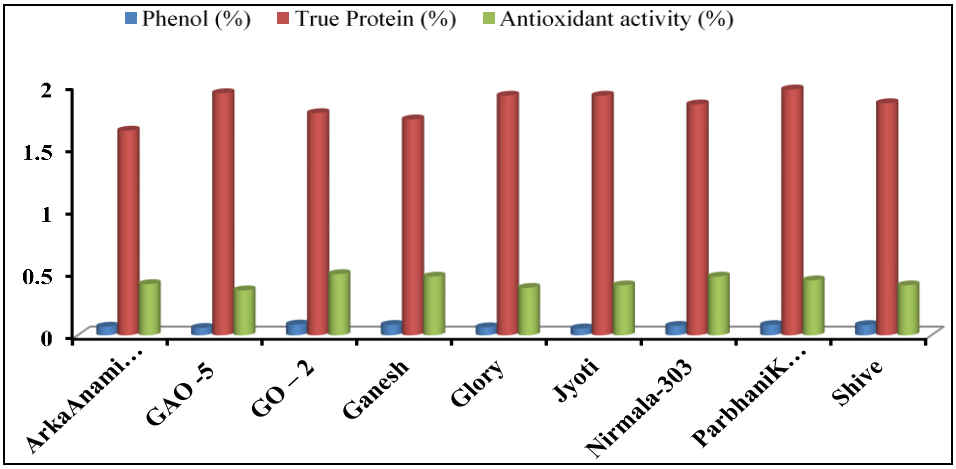

Fig 4: Phenol, true protein and antioxidant activity of different cultivars of okra

Table 5: Chlorophyll a, chlorophyll b, chlorophyll a/b, total chlorophyll and total carotenoid of different cultivars from okra fruits

Cultivar	Chlorophyll a (mg/g)	Chlorophyll b (mg/g)	Chlorophyll A/B (mg/g)	Total chlorophyll (mg/g)	Total carotenoids (mg/g)
Ankur-40	0.87	0.38	2.35	1.25	0.056
Arka Anamika	0.85	0.39	2.25	1.23	0.028
GAO -5	0.98	0.53	1.85	1.51	0.084
GO – 2	0.91	0.55	1.67	1.45	0.085
Ganesh	0.88	0.36	2.50	1.24	0.047
Glory	0.91	0.26	3.47	1.17	0.038
Jyoti	0.91	0.36	2.62	1.26	0.064
Nirmala-303	0.90	0.54	1.68	1.44	0.068
Parbhani Kranti	0.90	0.53	1.70	1.43	0.076
Shive	0.89	0.44	2.14	1.33	0.067
S.Em.±	0.03	0.04	0.22	0.03	0.004
C.D.@5%	0.09	0.10	0.67	0.10	0.011
CV%	5.61	14.04	17.51	4.18	10.72

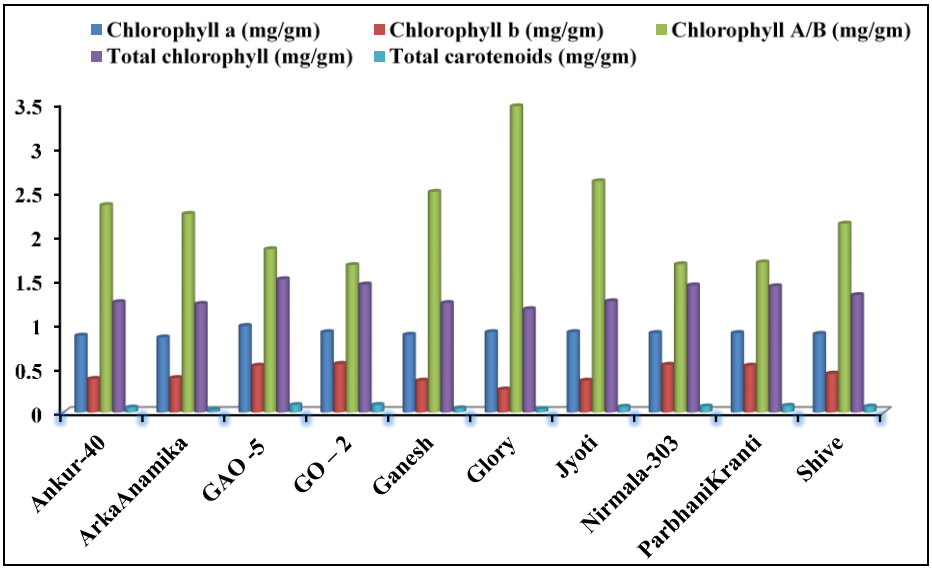

Fig 5: Chlorophyll a, chlorophyll b, chlorophyll A/B and total chlorophyll of different cultivars of okra

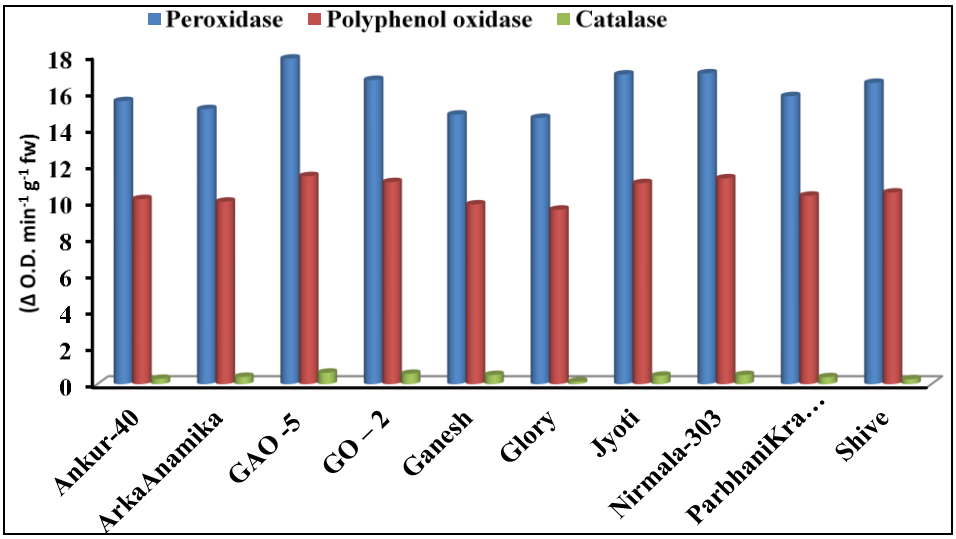

Fig 6: Peroxidase, polyphenol oxidase and catalase activity of different okra cultivars

Table 6: Peroxidase, polyphenol oxidase and catalase activity of different cultivars of okra

Cultivar	Peroxidase (Δ O.D. min^{-1} g^{-1}fw)	Polyphenol oxidase (Δ O.D. min^{-1} g^{-1}fw)	Catalase (Δ O.D. min^{-1} g^{-1}fw)
Ankur-40	15.51	10.139	0.289
Arka Anamika	15.07	9.997	0.398
GAO -5	17.84	11.398	0.627
GO – 2	16.67	11.071	0.564
Ganesh	14.77	9.848	0.502
Glory	14.59	9.560	0.139

Jyoti	16.97	11.014	0.459
Nirmala-303	17.03	11.277	0.500
Parbhani Kranti	15.78	10.324	0.380
Shive	16.51	10.500	0.268
S.Em.±	0.17	0.13	0.07
C.D.@5%	0.51	0.39	0.21
CV%	1.84	2.15	30.05

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