Research Article

Assessment of Key Brinjal (*Solanum melongena* L.) Cultivars Against Sucking Insect Pests and Economic Analysis Under Field Conditions in Peshawar, Pakistan

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Abstract | An experiment was conducted to study the population dynamics of sucking insect pests along with economic parameters on key brinjal cultivars at Newly Developmental Farms (NDF), The University of Agriculture Peshawar. Six different treatments, i.e., Nirala (T_1), Shamli hybrid (T_2), Cluster king (T_3), Purple long (T_4), Dilnasheen (T_5) and Bemisaal (T_6) were cultivated in randomized complete block design (RCBD) with three replications. Data were collected on the population dynamics of aphids (*Aphis gossypii*), jassids (*Amrasca biguttula*), whiteflies (*Bemicia tabaci*), host plant susceptibility index (HPSI), yield (ton ha^{-1}) and cost-benefit analysis, respectively. Results regarding the time interval data indicated that the highest insect populations were recorded in May. While screening results showed that Nirala and Shamli hybrid cultivars were found resistant against sucking insect pests of brinjal crops, it resulted in the lowest host plant susceptibility indices (HPSIs), higher yields, and the maximum cost-benefit ratio among the six tested cultivars. Thus, it can be hypothesized that Nirala and Shamli hybrid brinjal cultivars are highly resistant against sucking insect pest of brinjal crop and can be recommended for inclusion in integrated pest management (IPM) and sustainable development programs to minimize pest damage and improve brinjal production.

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Introduction

Brinjal, *Solanum melongena* Linnaeus is commonly grown vegetable of Solanaceae family also known as Aubergine (Kantharajha and Golegaonkar, 2004) cultivated in tropical and subtropical climatic zones (Kaushik *et al.* 2016). The Solanaceae family comprises approximately 2,450 species distributed across 95 genera, cultivated globally (Mabberley, 2008). Eggplant is rich in essential nutrients, including iron, calcium, phosphorus, potassium, vitamin B, water, protein, fiber, fat, minerals, carbohydrates, folic acid, ascorbic acid, and riboflavin (Bhatti *et al.* 2013). Extracts from brinjal are employed in traditional medicine for conditions such as diabetes, gonorrhea, cholera, bronchitis, diarrhea, and hemorrhoids.

Chlorogenic acid, a bioactive compound in eggplant, exhibits anticancer, cardioprotective, anti-obesity, analgesic, cholesterol-lowering, and antioxidant properties (Bello *et al*., 2005; Suroowan *et al*., 2019).

Globally, approximately 1.57 billion hectares of land are dedicated to crop cultivation, whereas in Pakistan, 30.94 million hectares are allocated for this purpose, Similarly, the global per capita cropland average is 0.20 hectares, while Pakistan falls below this average at 0.13 hectares per capita (FAO, 2024). The data indicate a progressive increase in the total cultivated area and production of vegetables in Pakistan over time. Between 2000-01 and 2017-18, the vegetable cultivation area expanded by 24%, while production exhibited a more substantial rise of 66% during the same period (GoP, 2018). In 2022, Pakistan's food exports amounted to 5,103 million USD, while food imports reached 9,070 million USD, resulting in a net trade deficit of 3,968 million USD (FAO, 2024). China, India, Egypt, Turkey, and Iran are the leading producers of eggplant globally, with China contributing 58% of the total production, followed by India at 25%, and significant outputs from Egypt, Turkey, and Iran (Younas *et al*., 2022). In Pakistan, Brinjal is cultivated over an area of 6,667 hectares, yielding an annual production of 95,001 tons (MNFSR, 2022-23), While in Khyber Pakhtunkhwa province, brinjal cultivation spans 1,045 hectares, producing 7,759 tons annually with average yield of 10.50-ton ha^{-1} (MNFSR, 2022-23). In Khyber Pakhtunkhwa, brinjal cultivation has shown minimal expansion over the five-year period from 2018-19 to 2022-23, with the cultivated area increasing marginally from 1,039 to 1,045 hectares (MNFSR, 2022-23). Conversely, brinjal production declined from 9,206 tonnes in 2018-19 to 7,759 tonnes in 2022-23. Despite this reduction in production, the average monthly wholesale price of brinjal in the major markets of Peshawar surged from 1,100 to 3,067 Rupees per 40 kg over the same period (MNFSR, 2022-23). Khyber Pakhtunkhwa's diverse climate, with temperatures ranging from below 0°C in the north to over 45°C in the south, supports a wide variety of crops, fruits, and vegetables, offering significant potential for the vegetable sector if proper attention is given and quality factors are addressed (Jalal-ud-Din, 2011).

The fructification cycle of eggplant is completed within three months. As a warm-season crop, eggplant thrives under a photoperiod of 10–12 hours and an optimal temperature range of 23°C-26°C however low temperatures of 10°C–12°C negatively influenced the growth of flowering and fruit sets (Sekara *et al*., 2007; Singh, 2018), these temperature ranges showed that brinjal cultivation is perfectly suitable for the climatic conditions Khyber Pakhtunkhwa, Pakistan. Eggplant height ranges from 0.4 to 1.5 meters, characterized by branching stems and broad leaves. Similarly, flowers of eggplant are hermaphroditic or male, complete, actinomorphic, star-shaped, and can be either hypogynous or epigenous. They may appear as solitary blooms or in clusters of 3 to 5 flowers. Flower diameter ranges from 3 cm to 5 cm (Daunay *et al*., 2001; Hassan *et al*., 2015).

In Pakistan, from cultivation till harvest, brinjal crops are severely damaged by various insect pests (Rai *et al*., 2014), among which, aphids (*Aphis gossypii*), jassids (*Amrasca biguttula*), thrips (*Thrips palmi* Karny), brinjal stem borer (*Euzophera perticella* Ragonot), fruit and shoot borer (*Leucinodes orbonalis* Guenee), leaf roller (*Eublemma olivacea* Walker) and whitefly (*Bemicia tabaci* Genn.) are the most important (Mehmood *et al*., 2002; FAOSTAT, 2010; Prasad *et al*., 2017; Yousafi *et al*., 2020; Ullah *et al*., 2022). Under the climatic conditions of Peshawar, *B. tabaci*, *A. biguttula biguttula*, *A. gossypii*, and *L. orbonalis* are the primary insect pests causing substantial damage to various brinjal (*Solanum melongena L.*) cultivars, including Shamli, Pearl Long, Local long, Black Neelam, Purple long and Black Beauty (Habib *et al*., 2015; Ayub *et al*., 2020 and Ullah *et al*., 2022).

A. gossypii both nymph and adult present on the lower side of leaf damaging young shoots and leaf surfaces by sucking cell sap. Light infestation results in yellowing of leaves while severe infestation causes leaf curling and deformation; also produces honeydew which leads to the development of soot mold fungi and disturbs the process of photosynthesis (Srinivasan, 2009). Aphids attack the crop at 35-40 days after transplanting (Choudhury *et al*., 2015). At the seedling stages of the crop, larvae attack foliar, while in later stages, flower buds and fruits are also attacked due to which the production is severely affected (Yousafi *et al*., 2020). In the months of July-October, 60% damages are caused by this pest to brinjal crop (Dhandapani *et al*., 2003). *A. biguttula biguttula* adult feed on the lower side of the leaves by sucking the sap from the plant, results in curling and yellowing of leaf by injecting the toxic material which lead to necrosis and ultimately causes almost 54% damage to brinjal crop (Khan *et al.*, 2015 and Chand *et al.*, 2024). Jassid infestation stunts plant growth, reduces bud and flower production, lowers yield, and transmits the mycoplasmal disease 'little leaf' resulting in significant economic losses (Thakar *et al.*, 2024). *B. tabaci* is highly polyphagous as both nymphs and adults feed on plant sap, leading to reduced plant vigor. Severe infestations cause leaf yellowing and abscission. This diurnal insect typically rests on the underside of leaves during nighttime. (Srinivasan, 2009).

Molecular, morphological and biochemical markers are used to evaluate the diversity and economic parameters in different cultivars of brinjal crops. Morphological markers are defined as observable physical traits, that are used to assess interspecific and intraspecific diversity (Prohens *et al.*, 2005; Ullah *et al.*, 2014). Data regarding the population dynamics of insect pest should be collected from randomly selected plants within each plot arranged in a randomized complete block design (Yousafi *et al.*, 2020). Weekly data collection on the population dynamics of sucking insect pests facilitates the identification of resistant brinjal (*Solanum melongena* L.) cultivars (Yousafi *et al.*, 2013). Furthermore, data should be conducted during early morning hours when the activity levels of the pests are minimal (Ashraf *et al.*, 2017). The host plant susceptibility indices (HPSIs) are a critical metric for identifying susceptible cultivars among the tested brinjal varieties (Ali *et al.*, 2014). The population dynamics of sucking insect pests exhibits temporal variation across different brinjal cultivars (Yousafi *et al.*, 2013). Similarly, data regarding yield also exhibits significant variation on different cultivars of brinjal crop (Ali *et al.*, 2014).

Synthetic chemicals such as organophosphates, pyrethroids, neonicotinoids and insect growth regulators are commonly used to control pests like aphids, whiteflies, borers and mites (Dwarka *et al.*, 2024). The application of *Bacillus thuringiensis* (Bt), Methoxyfenozide, and Emamectin Benzoate effectively reduces general pest damage, leading to increased brinjal yield (Sahu *et al.*, 2023). Chemical Insecticides are commonly used against aphids, jassids and whiteflies, but they are costly, environmentally harmful, contribute to resistance, and have adverse effects on beneficial insects (Hrynko *et al.*, 2021 and Ullah *et al.*, 2022).

Biological control utilizes natural enemies of insect pest, including predators, parasitoids and entomopathogens, for sustainable pest management (Dwarka *et al.*, 2024). Predators like coccinellids and lacewings regulate aphid and whitefly populations, while endo-parasites such as *Arescon enocki* and *Chrysoperla* spp. effectively control jassids (Sahito *et al.*, 2018). *Orius insidiosus* suppresses thrips, and parasitoids like *Encarsia formosa*, *Eretmocerus* spp., and *Chrysocharis pentheus* aid in managing *B. tabaci* population (Raina and Yadav, 2018). Extracts of *A. indica*, *E. globulus*, and *M. pulegium* have demonstrated significant efficacy, reducing aphid, jassid, and leaf hopper populations by 93–97%, 87–92%, and 25–73%, respectively (Maqsood *et al.*, 2023). Plant-based products, both crude and purified, have proven effective as herbicides, fungicides and bactericides (Jabeen *et al.*, 2021; Javaid *et al.*, 2022 and Saeed *et al.*, 2023), with recent studies highlight their effectiveness against insect pests, leading to higher production and improved cost-benefit analysis in brinjal cultivation (Maqsood *et al.*, 2023).

One of the most important factors in integrated pest management (IPM) strategies is host plant resistance which is environmentally friendly and can be used alone or in combination (Barzman *et al.*, 2015). Host Plant Resistance enhances integrated pest management (IPM) by reducing insecticide use and promoting natural enemy efficacy, where even low plant tolerance significantly decreases the need for chemical control (Deguine *et al.*, 2021). Host plant resistance can render crops unsuitable for insect pests without inducing inheritable resistance within the pest population (Mani *et al.*, 2022). Morphological and biochemical characteristics of plants significantly contribute to resistance; for instance, leaf trichome length on midrib, thickness of leaf lamina, nitrogen and manganese percentage exhibits a negative correlation with insect pest populations (Mani *et al.*, 2022 and Shah *et al.*, 2023). The selection of resistance cultivars is one of the most important methods of integrated pest management (Maqsood *et al.*, 2023). Screening of several cultivars has been carried out by researchers and growing resistance cultivars has been recommended by these experts (Shaukaet *et al.*, 2018 and Younas *et al.*, 2022). Brinjal is favored by breeders for its resilience, hardy nature, large flowers, and high seed yield from a single pollination event (Farooq and Delvadiya, 2023). The economic viability of brinjal cultivation has been enhanced by the cost-effective production of F1 seeds and the low seed requirement per unit area (Mishra *et al.*, 2023). Enhancing pest resistance in plants is vital for sustainable agriculture, reducing pesticide use, improving crop yields, and promoting environmental and food security (Kumari *et al.*, 2022). Keeping in view the importance of resistance cultivars, an experiment was conducted to record the economic parameters and population dynamics of *A. gossypii*, *A. biguttula biguttula* and *B. tabaci* on six important cultivars of brinjal crops.

Materials and Methods

An experiment was conducted to study the population dynamics of aphids (*Aphis gossypii*), whitefly (*Bemicia tabaci*) and jassids (*Amrasca biguttula*) along with economic parameters on six different brinjal cultivars at Newly Developmental Farms (NDF), The University of Agriculture Peshawar. Six different treatments, i.e., Nirala (T_1), Shamli hybrid (T_2), Cluster king (T_3), Purple long (T_4), Dilnasheen (T_5) and Bemisaal (T_6) were used in this experiment to find the resistant cultivar against sucking insect pests. The experiment was conducted in Randomized Complete Block design (RCBD) with three replications. Distance between row to row and plant to plant was kept 60 cm and 50 cm, respectively. A buffer zone of 2ft was kept isolating treatments and replications. During the cropping season, agronomic practices were carried out in each treatment.

Population dynamics of aphids, jassids and whiteflies

Five plants from each replication were selected and tagged for recording data on aphids (nymph + adult), jassids (nymph + adult), and whiteflies (nymph + adult). Data collection did not include the nursery period. Observations were made biweekly over a four-month period, starting from the commencement of the experiment. Three leaves (one each from the top, middle, and bottom) were randomly selected per plant, and the number of sucking insect pests were recorded visually in the early morning when insect activity was minimal. The mean population density of sucking insect pest was calculated for each block. (Ashraf *et al.*, 2017; Yousafi *et al.*, 2020).

Host plant susceptibility indices (HPSIs)

The host plant susceptibility index (HPSI) was calculated to assess the per-leaf vulnerability of selected brinjal cultivars to sucking insect pests. Individual and cumulative indices were determined using Microsoft Excel on an IBM-compatible system. The HPSI (%) was derived using the formula (Ali *et al.*, 2014):

$$\text{HPSI (\%)} = \frac{A}{B} \text{ x } 100$$

Where:

- *A* represents the pest population (adults and nymphs) on a specific cultivar.
- *B* represents the submission of pest population (adults and nymphs) across all cultivars.
- Yield (ton ha^{-1})
-

Fruits were harvested at 1–2 cm width and 5–10 cm length, while overripe fruits, identified by a brown hue, spongy texture, and crinkled skin, were excluded. In three replicates, mature, healthy fruits were collected weekly. Fruits from each treatment were weighed using an electronic balance, and the average yield was calculated in ton ha^{-1} (Ullah *et al.*, 2022).

Cost-benefit analysis

For the calculation of cost benefit ratio, input expenses for land preparation, seeds, and labor required from cultivation to harvest were recorded as unit costs per hectare. The market value of brinjal was calculated based on wholesale prices in Peshawar. The Cost-Benefit Ratio (CBR) was computed using standard methodology.

Treat-ments	Mar-ketable Yield (kg ha^{-1})	Gross revenue in rs. per ha=mar-ketable yield x price kg^{-1})	Total cultiva-tion cost	CBR=-Gross revenue/ cultivation cost

Statistical analysis

All the recorded data were analyzed statistically by using two factorial Randomized Complete Block Design (RCBD) in STATISTIX (8.1) software. Means were separated by using Least Significance Difference Test at 5% level of significance (Steel and Torrie, 1980).

Results and Discussion

Population trend of aphids (A. gossypii) leaf^{-1} on six different brinjal cultivars under field conditions at Newly Developed Malakandair Farms, Peshawar.

Table 1: *Aphid (Aphis gossypii) population trends leaf⁻¹ on six brinjal cultivars under field conditions at newly developed malakandair farms, Peshawar.*

Cultivar	Time interval								Mean
	15th Mar	1st Apr	15th Apr	1st May	15th May	1st June	15th June	1st July	
Nirala (T_1)	6.99q	13.33l	16.62ij	17.04i	13.16l	8.80p	5.81r	3.23s	10.62e
Shamli hybrid (T_2)	5.79r	12.28mn	15.78k	16.71ij	12.27o	7.65q	5.91r	2.97s	9.85 e
Cluster king (T_3)	12.27mn	19.19g	26.09c	26.35c	15.98jk	13.03lm	8.74p	3.56s	15.65c
Purple long (T_4)	8.79p	16.71ij	23.31ef	23.55e	15.70k	11.05o	7.16q	3.10s	13.67d
Dilnasheen (T_5)	16.02jk	23.90	29.86b	29.52b	22.74f	17.11i	11.64no	6.96q	19.72b
Bemisaal (T_6)	19.38g	24.83d	34.65a	34.54a	26.17c	18.24h	11.12o	7.34q	22.03a
Mean	11.53c	18.37b	24.38a	24.69a	17.50b	12.64c	8.40d	**4.52e**	

Those means which have the same alphabet are not statistically different from one another at 5% level of significance using LSD test (P < 0.05)
LSD for cultivars= 1.2742
LSD for time interval= 1.3166
*LSD for cultivars*time interval= 0.7756*

Table 2: *Jassids (Amrasca biguttula biguttula) population trends leaf⁻¹ on six brinjal cultivars under field conditions at newly developed malakandair farms, Peshawar.*

Cultivar	Time interval								Mean
	15th Mar	1st Apr	15th Apr	1st May	15th May	1st June	15th June	1st July	
Nirala (T_1)	1.44stu	2.65no	3.75j	3.83ij	2.22pq	2.49o	1.17wx	0.33y	2.23e
Shamli hybrid (T_2)	1.55rst	2.78mn	3.93hi	3.99hi	231p	2.51o	1.24vwx	0.36y	2.33d
Cluster king (T_3)	2.19pq	3.21kl	4.77ef	4.69efg	3.09l	3.31k	1.61r	1.20wx	3.01c
Purple long (T_4)	2.18pq	3.23kl	4.77ef	4.84e	3.13l	3.33k	1.60rs	1.13x	3.03c
Dilnasheen (T_5)	3.17kl	5.10d	7.15b	7.36a	4.62fg	4.77ef	2.15pq	1.39tuv	4.46a
Bemisaal (T_6)	2.83m	4.59g	6.59c	7.13b	4.02h	4.01h	2.08q	1.31uvw	4.07b
Mean	2.23e	3.59c	5.16a	5.31a	3.23e	3.41d	1.64e	**0.95ef**	

Those means which have the same alphabet are not statistically different from one another at 5% level of significance using LSD test (P < 0.05)
LSD for cultivars= 0.1953
LSD for time interval= 0.3592
*LSD for cultivars*time interval= 0.1676*

The results indicate that the population of *A. gossypii* leaf⁻¹ varied significantly among six brinjal cultivars (Table 1). The highest mean population of *A. gossypii* leaf⁻¹ was observed on the Bemisaal cultivar followed by Dilnasheen and Cluster king cultivars, respectively. In contrast, the lowest mean population of *A. gossypii* leaf⁻¹ was recorded on the Shamli hybrid, followed by the Nirala cultivar, with no significant difference between these two cultivars. The perusal of data regarding time interval demonstrated that *A. gosyypii* peaked at the end of April and during the first half of May and diminished during the month of July. Additionally, it was revealed that *A. gossypii* exhibited significantly higher population on the Bemisaal cultivar throughout the experiment, whereas the lowest densities were observed on the Shamli hybrid cultivar. Our results are in conformity with Habib *et al*. (2015) who observed the infestation of *A. gossypii* three weeks after transplanting, with the maximum infestation recorded in mid-May on different brinjal cultivars. Similarly, Patel *et al*. (2015) reported aphid infestation from the beginning to the termination of the crop cycle, recording the highest population density in May. The findings of this study on the susceptibility and resistance of brinjal cultivars align with those of Yousafi *et al*. (2020), who reported that the Nirala cultivar exhibited significant resistance to *A. gossypii* compared to the Bemisaal and Dilnasheen cultivars. Similarly, Ayub *et al*. (2020) found the Shamli hybrid cultivar resistant, aligning with our findings, but reported the Purple Long cultivar as highly susceptible, whereas our study classified it as moderately resistant among six tested cultivars. They also observed that the *A. gossypii* population peaked during the second week of May and declined by the end of June. Beyond chemical control, botanicals like *A. indica* have been extensively studied, with azadirachtin identified as a key insecticidal compound. It acts as a repellent, antifeedant, and sterilizing agent (Chaudhary *et al*., 2017) as well as various bioactive compounds from *A. indica* leaves contribute to its insecticidal properties (Ahmad *et al*., 2019 and Khan and Javaid, 2021).

Population trend of jassids (amrasca biguttula) leaf^{-1} on six different brinjal cultivars under field conditions at newly developed malakandair farms, Peshawar

The results indicate significant variation in the population of *A. biguttula biguttula* leaf^{-1} among the tested brinjal cultivars (Table 2). The highest mean population of *A. biguttula biguttula* leaf^{-1} was observed on the Dilnasheen brinjal cultivar, followed by Bemisaal, Purple Long, and Cluster King brinjal cultivars, respectively. However, significantly lowest mean population density was recorded on the Nirala cultivar, followed by the Shamli hybrid brinjal cultivar. The analysis of the time interval data revealed that the population of *A. biguttula biguttula* reached its peak at the end of April and during the first half of May, subsequently declining in July. Furthermore, it was revealed that *A. biguttula biguttula* consistently exhibited higher populations on the Dilnasheen cultivar throughout the experiment, whereas the lowest densities were observed on the Nirala brinjal cultivar. The findings of this study on the susceptibility and resistance of brinjal cultivars align with those of Yousafi *et al*. (2013), who reported that the Nirala cultivar exhibited significant resistance to *A. biguttula biguttula* compared to the Bemisaal and Dilnasheen cultivars. Similarly, Ashraf *et al*. (2017) reported that Shamli hybrid brinjal cultivar showed resistance to *A. biguttula biguttula* as compared to tested cultivars. Our results regarding *A. biguttula biguttula* population ranging from 2.23 to 4.46 leaf^{-1}, differ from Elanchezhyan *et al*. (2008), who reported a range of 0.00 to 6.80 per leaf across 25 brinjal varieties, likely due to differences in varieties and experimental locations. Our findings regarding the time interval align with Ali *et al*. (2016), who reported that *A. biguttula biguttula* infestation began in April, peaked in May, and declined by late June. Similarly, Mahmood *et al*. (2002) observed that *A. biguttula biguttula* populations were positively correlated with high temperatures and negatively correlated with rainfall. Halder *et al*. (2023) investigated the effects of entomopathogenic fungi, botanicals, and chemicals, reporting the lowest jassid (1.77, 2.33/leaf) and whitefly (1.41, 1.63/leaf) populations in plots treated with entomopathogenic fungi, comparable to (Chemical) Imidacloprid.

Population trend of whiteflies (bemicia tabaci) leaf^{-1} on six different brinjal cultivars under field conditions at newly developed malakandair farms, Peshawar.

The results indicate that the population density of *B. tabaci* leaf^{-1} varied significantly across six brinjal cultivars (Table 3). The maximum mean population density was recorded on the Bemisaal cultivar, followed by Dilnasheen, Cluster King, and Purple Long brinjal cultivars. In contrast, the minimum mean population density was observed on the Nirala, followed by the Shamli hybrid cultivar. The data regarding time interval indicated that the population of *Aphis gossypii* remains significantly higher during

Table 3: *Whitefly (Bemicia tabaci) population trends leaf^{-1} on six brinjal cultivars under field conditions at newly developed malakandair farms, Peshawar.*

Cultivar	Time interval								Mean
	15th Mar	1st Apr	15th Apr	1st May	15th May	1st June	15th June	1st July	
Nirala (T_1)	7.48t	8.66rs	11.54n	14.72gh	13.87ij	9.32pqr	4.49vw	3.90w	8.25e
Shamli hybrid (T_2)	7.50t	8.74rs	12.08mn	14.93g	14.08hi	9.86p	5.04v	3.90w	9.51d
Cluster king (T_3)	8.29s	9.86p	13.13kl	17.92d	17.21e	13.64ijk	9.07qr	6.11u	11.90c
Purple long (T_4)	8.36s	9.63pq	12.52lm	18.27cd	16.51ef	13.27jk	8.91rs	5.97u	11.68c
Dilnasheen (T_5)	10.65o	14.85g	18.85c	26.93a	26.44a	18.41cd	12.15mn	6.62u	16.86b
Bemisaal (T_6)	14.02hi	15.12f	20.84b	26.71a	27.01a	18.80c	13.89ij	6.66u	18.01a
Mean	9.38f	11.31e	14.83c	19.91a	19.19b	13.88d	8.92g	**5.53h**	

Those means which have the same alphabet are not statistically different from one another at 5% level of significance using LSD test (P < 0.05)
LSD for cultivars= 0.2503
LSD for time interval= 0. 2890
LSD for cultivars time interval = 0.7079*

the month of May and gradually declined by July. Additionally, it was revealed that *B. tabaci* consistently exhibited higher populations on the Bemisaal cultivar throughout the experiment, while the lowest densities were recorded on the Nirala cultivar. Muthukumar and Kalyanasundaram, (2003) stated that *B. tabaci* appeared initially after the first week of transplanting and remained active throughout the cropping season. Our findings align with Ayub *et al.* (2020), who reported the Shamli hybrid as resistant to *B. tabaci*. However, they classified the Purple Long as resistant cultivar against *B. tabaci*, whereas our study categorized it as moderately susceptible among the six tested cultivars. Both studies observed similar trends regarding the peak population of *B. tabaci*. Furthermore, Patel *et al.* (2015) have demonstrated a positive correlation between *B. tabaci* populations and maximum and minimum temperatures, and a negative correlation with rainfall and relative humidity. Abubakar *et al.* (2023) studied the eco-friendly management of *B. tabaci* and revealed that neem leaf extract (60ml/L) was found highly effective against whiteflies (1.2-1.3 adults leaf^{-1}) resulting in better production.

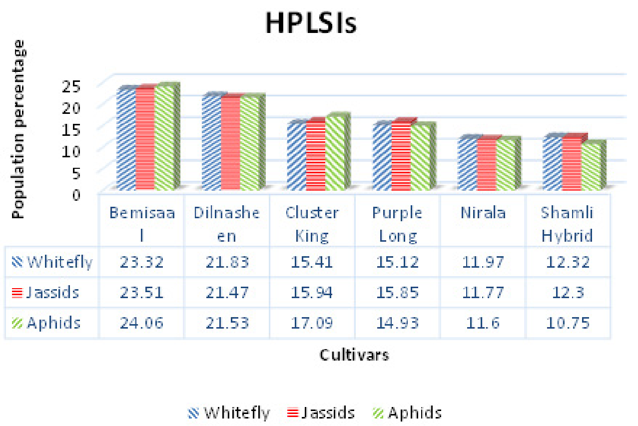

Figure 1: *Host plant susceptibility indices (HPSIs) of six different brinjal cultivars against sucking insect pest under field conditions, Peshawar.*

Host plant susceptibility indices (HPSIs) of six different brinjal cultivars against sucking insect pest under field conditions.

The host plant susceptibility indices (HPSI) based on the population densities of *A. gossypii*, *A. biguttula biguttula*, and *B. tabaci* across six brinjal cultivars are presented in Figure 1. The results indicate that the Bemisaal genotype exhibited the highest HPSI values, at 23.20% for *B. tabaci*, 23.51% for *A. biguttula biguttula*, and 24.06% for *A. gossypii*, identifying it as the most susceptible cultivar, followed by Dilnasheen. In contrast, the lowest HPSI values were recorded for Nirala, with 11.97% for *B. tabaci* and 11.77% for *A. biguttula biguttula*, and for Shamli hybrid, with 10.75% for *A. gossypii*, followed by Purple Long and Cluster King cultivars. These findings are consistent with the results of Ali *et al.* (2014), who categorized various brinjal cultivars into resistant and susceptible groups based on host plant susceptibility indices (HPSIs). Based on the HPSI results, two cultivars, Nirala and Shamli Hybrid, were identified as resistant, while Cluster King and Purple Long exhibited intermediate resistance. While, the remaining cultivars, Bemisaal and Dilnasheen, were classified as susceptible to sucking insect pests of brinjal crops. Furthermore, through host plant resistance, insect damage has been minimized (Mouden *et al*., 2017). Resistant eggplant varieties possess thick, elongated clasping calyxes that hinder larval penetration (Dar *et al*., 2017). Narrow, elongated, and hairy fruits exhibit lower infestation rates due to reduced pest preference for oviposition (Gautam *et al*., 2019). Additionally, pericarp thickness shows a positive correlation with infestation, whereas trichome density is negatively correlated (Challa *et al*., 2021).

Table 4: *Impact of six different brinjal cultivars on fruit Yield (ton ha^{-1}) under field condition at newly developed malakandair farms, Peshawar.*

Treatments	Yield plant^{-1}	Yield (Ton ha^{1})
Nirala (T_1)	1.079 a	14.953 a
Shamli hybrid (T_2)	0.933 b	13.477 b
Cluster king (T_3)	0.768 c	10.407 c
Purple long (T_4)	0.817c	10.627 c
Dilnasheen (T_5)	0.501 d	7.653 e
Bemisaal (T_6)	0.447 d	8.263 d
LSD	0.1031	0.4511
F	56.16	398.98
P-Value	0.0000	0.0000

Impact of six different brinjal cultivars on fruit Yield (ton ha^{-1})

Fruit yield is a critical parameter from the perspective of farmers' economics. A significant variation in yield (ton ha^{-1}) was observed among the six brinjal cultivars (Table 4). The Nirala cultivar recorded the highest yield (14.95-ton ha^{-1}), followed by the Shamli hybrid (13.47-ton ha^{-1}). However, the Dilnasheen cultivar exhibited the lowest yield (7.65-ton ha^{-1}), followed by the Bemisaal and Cluster King cultivars, with yields of

Table 5: *The Cost-benefit ratio of six various brinjal cultivars under field conditions at at newly developed malakandair farms, Peshawar.*

Treatments	Marketable yield (kg ha^{-1})	Gross revenue in rs. ha^{-1} = marketable yield x price kg^{-1}	Total cultivation cost	CBR=Gross revenue/cultivation cost
Nirala (T_1)	14953	448590	76514	1:5.86
Shamli hybrid (T_2)	13477	404310	79864	1:5.06
Cluster king (T_3)	10407	312210	75284	1:4.14
Purple Long (T_4)	10627	318810	76145	1:4.18
Dilnasheen (T_5)	7653	229590	77689	1:2.95
Bemisaal (T_6)	8263	247890	77468	1:3.19

Average wholesale market brinjal price kg^{-1} in Peshawar= Rs. 30/-

8.26 and 10.40-ton ha^{-1}, respectively. These findings are consistent with those of Rehman *et al.* (2019), who reported the highest fruit yield $plant^{-1}$ for the Nirala cultivar as compared to other tested cultivars. Similar results were also documented by Javed *et al.* (2017). However, the observed fruit yield per plant differs from the findings of Kundu *et al.* (2023), who reported yields ranging between 1.08 and 7.65 kg $plant^{-1}$. This variation may be due to differences in the tested brinjal cultivars and the environmental conditions at the experimental sites.

Effect of six different brinjal cultivars on Cost-benefit ratio

Table 5 summarizes the cost-benefit ratio analysis for the six tested brinjal cultivars. The data reveal that the Nirala cultivar achieved the highest cost-benefit ratio (1:5.86), followed by the Shamli hybrid (1:5.06). In contrast, the Dilnasheen cultivar exhibited the lowest cost-benefit ratio (1:2.95), followed by Bemisaal (1:3.19), Cluster King (1:4.14), and Purple Long (1:4.18), respectively. These results are in agreement with the findings of Gogoi *et al.* (2018), who reported significant variation in the cost-benefit ratio among different brinjal cultivars, with values ranging from a maximum of 5.35 to a minimum of 0.92, respectively. Similar findings were reported by Sahu *et al.* (2022), who conducted an evaluation of different brinjal cultivars and reported significant variability in the economic performance of the tested cultivars as highest cost-benefit ratio recorded was 3.87, while the lowest cost-benefit ratio observed was 1.06, respectively. Athawale *et al.* (2023) reported the highest cost-benefit ratio of 2.64 in small-scale farms, followed by 2.52 in medium-scale and 2.47 in large-scale farms. Yousafi *et al.* (2016) reported the highest cost-benefit ratio of 1:5.40 in plots treated with Emamectin Benzoate applied four times, followed by Spinosad with a ratio of 1:3.72. Cultural practices significantly influence the cost-benefit analysis of brinjal, with the highest benefit ratio (1:6.3) observed in plots implementing mulching and clipping, compared to the control (1:1.8) (Muhammad *et al.*, 2021).

These results align with the current study, further emphasizing the influence of cultivar selection on economic outcomes in brinjal production.

Conclusions and Recommendations

Nirala and Shamli hybrid demonstrated resistance to sucking insect pests of brinjal crops, exhibiting the lowest host plant susceptibility indices, higher yields, and the maximum cost-benefit ratio among the six tested cultivars. Thus, it can be hypothesized that Nirala and Shamli hybrid brinjal cultivars are highly resistant against *A. gossypii, A. biguttula and B. tabaci* and can be recommended to farmers for the commercial production and inclusion in integrated pest management (IPM) programs under the climatic conditions of Peshawar. Furthermore, Climate change is anticipated to influence pest distribution and severity, necessitating the development of pest forecasting models and climate-resilient brinjal varieties for effective pest management.

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Novelty Statement

This study aims to identify the most resistant brinjal cultivar against sucking insect pests with superior economic parameters and to recommend that cultivar to farmers for commercial production under the climatic condition of Peshawar.

Author's contribution

Muhammad Anwar Khan: Designed and supervised the experiment.
Mehran Ullah: Conducted the experiment, analyzed data, and wrote the manuscript. All authors read and approved of the final manuscript.

Generative AI or AI assisted technology statement
No AI technology has been used in this whole experimental research trial.

Conflict of Interest
The authors declares that there is no conflict of interest regarding the publication of this article

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