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Analysis of Weed Distribution Patterns in Cotton Agroecosystems Using Raunkiaer's Frequency Classes

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Abstract
Raunkiaer's frequency class approach was used to perform a comparative analysis of weed distribution patterns in cotton agroecosystems in chosen regions of Shrirampur and Rahuri. The study sought to determine the floristic composition, frequency distribution, and behavior of weed species found in cotton fields under various agroecological circumstances. While phytosociological research was done between 2020 and 2022 utilizing the random quadrat sampling method, weed collecting was done between 2019 and 2025. Weed species were identified, documented, and assigned to Raunkiaer's frequency classes based on their occurrence frequency. The study found significant variance in weed flora across the two locations, suggesting changes in soil properties, irrigation strategies, and crop management systems. Comparative investigation revealed that weed infestation and species variety were higher in Rahuri than in Shrirampur, probably due to differences in moisture availability and agronomic techniques. The Raunkiaer frequency distribution pattern diverged from the expected biological spectrum, indicating ecological instability and ongoing disturbance in cotton agroecosystems. The study's findings provide useful insights into weed ecology and dispersion dynamics, which can help to build region-specific integrated weed management techniques for sustainable cotton agriculture.

Keywords: Weed, Cotton, Crop Management, Frequency Class, Development, Shrirampur, Rahuri, etc.

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Introduction
The operations
Cotton, also known as "white gold" or "the king of fibres," is one of India's most important commercial crops. Cotton (Gossypium hirsutum) is a natural fiber that is widely utilized in a variety of industries and grown in over 70 countries worldwide. Cotton is a significant cash crop in India due to its importance in agriculture, industrial development, and job creation(Sathishkumar et al., 2016). Cotton is primarily produced for its fibre, which is widely utilized as a textile raw material. Cotton is a key commodity in the global economy. Weeds create losses in agricultural production situations, including decreased crop yield, poor crop quality, increased irrigation expenses, increased harvesting costs, decreased land value, livestock injury, and crop damage from insects and diseases harboured by these weeds(Akhil et al., 2024).

Figure 1 Cotton Crop

However, inadequate weed management and the presence of weeds in cotton fields can result in quality and output losses of up to 90%. Weeds compete with crops for nutrients, water, and light, and they also serve as pathogen hosts, causing illnesses and impairing crop harvesting and management. Weed infestation in cotton has been found to cause significant competition, resulting in output reductions of 40 to 85 percent(Manalil et al., 2017). Weeds that develop with cotton plants pose intense competition and cause a significant drop in seed cotton output. Reduction in seed cotton production under irrigated conditions is primarily due to nutrient depletion caused by weeds, which can range from 10-90 percent. Weed infestation in cotton has been found to cause significant competition and a production drop of 74%. Uncontrolled weed growth during the crop growing season resulted in yield losses of up to 86%. Previous research has demonstrated that a restricted presence of weeds can increase crop output by fostering beneficial microbial activity in the soil and preventing erosion(B. Singh & Garg, 2022).

Importance of cotton agroecosystems

Agroecosystems are ecosystems that promote food production on farms and gardens. As the name implies, agriculture is central to an agroecosystem. As such, they serve as the foundation for research in agroecology and regenerative agriculture, both of which employ ecological techniques(A. N. Rao & Chauhan, 2015). Agroecosystems are human-managed, modified ecosystems that generate food, fiber, and fuel, and they are the primary focus of agroecology research. Crops, livestock, and surrounding habitats interact with human-driven inputs like as irrigation, fertilization, and labor. These systems cover around 47% of land and substantial areas of the world(Ashok, 2024).

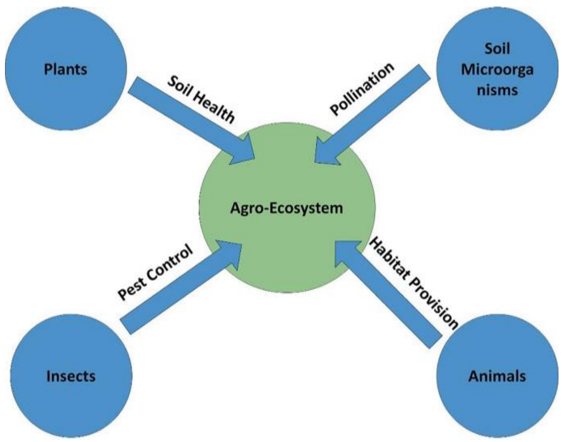


Figure 2 Agroecosystems and Its Benefits

Cotton is a valuable material that is widely utilized in the garment industry as well as other products like cotton swabs and cottonseed oil. Cotton accounted for almost 75% of global fibre use in the early 1900s; however, cotton now accounts for less than 30% of total fibre consumption. In the mid-1990s, synthetic fibres overtook natural fibres. Water shortages, climate change, and pest concerns were all contributing factors to the reduction(B. V Rao & Nadiu, 2017). Cotton is one of the most important cash crops in developing countries. Cotton production has been a crucial economic component and engine of economic progress in India. Cotton is produced under a variety of environmental, climatic, and political situations, which can lead to a variety of practices and outcomes. Cotton production in India has fluctuated despite government and other funders' initiatives(Sathishkumar et al., 2016). While cotton helps to drive economic growth, a lack of attractive investment opportunities in the industrial and service sectors limits agriculture's growth potential. The additional issues of the sector are social and economic, which are created by the overuse of pesticides, high production costs, and unstable market pricing(B. V Rao & Nadiu, 2017).

Cotton is a part of our daily life, from drying our faces with a nice cotton towel in the morning to sliding between new cotton sheets at night. It has hundreds of applications, ranging from blue denim to shoe strings(Meena et al., 2017). Clothing and home items are the most common uses, although industrial products account for many thousands of bales. Every part of the cotton plant is useful. The most important is the fiber, or lint, that is used to make cotton cloth. Linters, or short fuzz on the seed, offer cellulose for the production of polymers, explosives, and other items. Linters are also included into high-quality paper goods and processed into batting for padding beds, furniture, and car seats(Ambadas & Po, 2021).

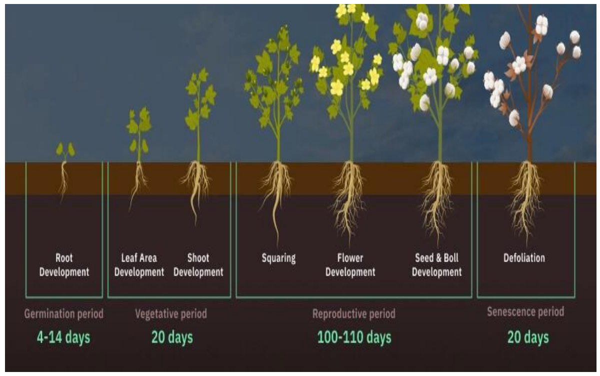


Figure 3 Cotton Growing: Sustainable Planting, Care and Harvest Methods

Cottonseed is crushed to provide three products: oil, meal, and hulls. Cottonseed oil is mostly used as a shortening, cooking oil, and salad dressing. The remaining grain and hulls are utilized as livestock, poultry, and fish feed, as well as fertilizer. Cotton stalks and leaves are trampled into the soil to enhance it. Cottonseed is also utilized as a high-protein concentrate in baked pastries and other food products(Ashok, 2024).

Effect of weeds on growth components of cotton

Weeds have a substantial negative impact on cotton development components because they compete with the crop for critical resources such nutrients, moisture, sunlight, and space. Weeds develop quickly during the early phases of crop establishment, suppressing normal cotton plant growth, resulting in poor seedling vigor and a reduced plant population(Naidu, 2012). Weed infection reduces plant height, leaf area, the number of monopodial and sympodial branches, and overall biomass accumulation in cotton. Weeds also inhibit photosynthetic efficiency by shadowing the crop canopy and lowering light interception, ultimately affecting dry matter production(B. Singh & Garg, 2022).

In addition, competition for soil resources, particularly nitrogen, phosphorus, and potassium, causes nutritional deficit in cotton plants, limiting vegetative and reproductive growth. Moisture stress induced by aggressive weed species further inhibits root development and nutrient uptake efficiency(B. V Rao & Nadiu, 2017). Some weeds may also serve as alternate hosts for insect pests and illnesses, so influencing crop health and growth performance. Prolonged weed competition during the key growth period considerably slows flowering and boll development, leading to poor crop establishment and poorer output. Therefore, proper weed management is vital to sustain the healthy growth and optimal development of cotton plants in agroecosystems(Vasave et al., 2025). Weeds have a substantial impact on cotton output and quality because they compete for water, nutrients, light, and space during the crop growth period. Uncontrolled weed growth during critical stages of crop development affects boll production, weight, and quantity of bolls per plant, resulting in significant output losses(Chen et al., 2024). A heavy weed infestation slows normal plant growth and reduces photosynthetic activity, resulting in insufficient assimilate buildup for seed cotton production. Weeds can cause significant reductions in seed cotton output depending on weed density, species composition, and duration of competition. Weeds also interfere with harvesting processes, increasing labor and production expenses(B. singh et al., 2022).

Weeds not only reduce yield, but they also have a negative impact on cotton fiber quality criteria. Weed-induced competition stress frequently results in shorter fiber length, poorer fiber strength, low micronaire value, and a lower lint percentage. Weed seeds, plant debris, and other foreign elements contaminate kapas during harvesting and processing, lowering market quality. Certain creeping and broad-leaved weeds can discolor or harm cotton lint, lowering its commercial value and spinning efficiency. Furthermore, weeds serve as alternate hosts for insect pests and diseases, lowering boll quality and fiber properties. As a result, prompt and efficient weed management is critical not just for optimizing cotton yield but also for ensuring exceptional fiber quality and economic returns(Thakur et al., 2025).

Preventive measures for weed management in cotton

During the summer, thoroughly till the area to remove any weeds that may have grown. For at least two to three weeks, expose the field to the sun. In between the widely separated cotton rows, grow short-duration legumes like cowpeas and lablab (inter-row cultivation), which can serve as cover crops or live mulch to reduce weed development and enhance soil health. Use plastic mulch or organic mulch (such as dry leaves or paddy straw) to prevent weed development by obstructing sunlight and lowering soil moisture(Mukherjee, 2025). To stop the weed cycle, alternate cotton crops with non-host crops like grains or legumes. Adhere to other agronomic techniques, such as managing irrigation, fertilizer, and "weed-seed free" seeds. To maximize early season moisture and reduce weed growth, plant the crop at the optimal period. To keep the field weed-free in the early days, do timely hand weeding(Malinga, 2021).

Growers can create more efficient weed management plans that are particular to the sorts of weeds found in cotton fields, such as grass weed or broad-leaved weed(P et al., 2022). To manage weeds in cotton fields, herbicides can be used either before or after emergence. The right herbicide should be carefully chosen according to the crop stage and weed species. The first 45 days are crucial for controlling weeds in cotton crops. To target particular weeds while lowering the possibility of harm to non-target species and the environment, use selective herbicides(Agrawal & Singh, 2025).

When applying herbicides before and after emergence, make sure the soil is moist. If rain is predicted, don't spray(Nalini & Chinnusamy, 2019). Rotating herbicide products with various ingredients is a good way to reduce weed resistance. For best results, post-emergence herbicide use is advised when the weeds have two to three leaves. To boost the effectiveness of post-emergence herbicides, use a sticking and spreading agent such as Multiplex Nagastha-180 (0.4–0.5 ml/lit of spray solution). Only clear, sunny days should be used for spraying. To stop herbicides from drifting, it is best to avoid spraying them in the direction of the wind(K. Singh et al., 2016). Pay close attention to the prescribed rates, application schedule, and safety recommendations listed on the herbicide label. Avoid tank mixing with herbicides that include sulfur and copper(Agrawal & Singh, 2025).

Literature Review

One of the main issues limiting cotton agroecosystems' sustainability and productivity is weed invasion. Weeds reduce crop growth, output, and fiber quality by fiercely competing with cotton plants for vital resources including nutrients, water, sunlight, and space. According to a number of studies, crop management approaches, soil type, irrigation techniques, and climate all affect the distribution and composition of weed flora. Developing efficient and region-specific weed management tactics requires an understanding of weed dispersion patterns. Frequency analysis has been shown in earlier research to be useful in determining dominant weed species and evaluating ecological stability in agricultural landscapes. Consequently, a comparative study of weed distribution patterns in cotton agroecosystems promotes sustainable cotton production methods and offers insightful information about weed ecology.

J. B. Vasave, [2025] discovered non-significant outcomes in both the pooled and individual years. Under treatment W6 (Weed free up to harvest), weed significantly reduced total nutrient depletion (nitrogen, phosphorus, and potassium). The values were nitrogen 0.27, 0.23, and 0.25 percent, phosphorus 0.07, 0.06, and 0.06 percent, and potassium 0.38, 0.32, and 0.35 percent during both individual years and in pooled results, respectively. However, it did not change with the W5, W4, and W7 treatments. In contrast, the treatment W12 (Weedy up to harvest) had the highest overall nutrient depletion, with nitrogen values of 13.34, 11.35, and 12.34 percent, phosphorus values of 3.01, 2.73, and 2.87 percent, and potassium values of 14.37, 12.19, and 13.28 percent during 2020–2021 and in pooled findings, respectively.

Dhiman Mukherjee, [2025] describes the organization of mustard crop weed communities and their phytosociological characteristics under edaphic fluctuation. Six distinct blocks in the Jhargram district underwent phyto-sociological research of the weed flora in Rabi 2022–2023 and 2023–2024. In red-latertic soil, a total of 15 families with 25 distinct species of weed flora were identified, which hinder crop growth and lower mustard production. Cynodon dactylon and Oxalis corniculata were found to have a high relative density, abundance percentage, and important value index with distinct weed flora composition. Physalis minima. Euphorbia hirta Spermacoce alata in several Jhargram district blocks. Cyperus rotundus scored a high important value index among the various sedges. Poa annua and Cirsium arvensis D. indicate the lowest important value index. Blumea lacera and Aegyptium show that their populations are quite small in various weed communities and do not require extremely strict control tactics. Additionally, control of Oxalis corniculata and Cynodon dactylon. Physalis minima. In the red-latertic belt of West Bengal, Euphorbia hirta and Cyperus rotundus become crucial for high mustard crop output.

Aditi Agrawal, [2025] examines different agronomic strategies for efficient weed control and talks about how weeds affect cotton productivity. A variety of weed control techniques are covered, such as chemical interventions (like herbicides), mechanical techniques (like hoeing and inter-row cultivation), cultural practices (like crop rotation and intercropping), and preventive measures (like clean cultivation and weed-free seeds). Every technique has benefits and drawbacks, thus an integrated strategy is required for long-term weed control. This review comes to the conclusion that effective weed control in cotton requires an integrated weed management strategy that combines several tactics suited to particular agro-ecological circumstances.

K Akhil, [2024] provides a succinct summary of study findings from various regions in relation to efficient weed control techniques in cotton farming. Known as the "King of natural fibre" and sometimes referred to as "White gold," cotton is a crucial economic commodity in India's agricultural landscape. It is a member of the Malvaceae family and species Gossypium. However, cotton develops slowly in its early stages, and the wide row spacing that is typically employed gives many weed species plenty of room to flourish. By competing with cotton for vital resources like water, light, air, and nutrients, they in turn present a serious obstacle to cotton's growth potential. Adopting a single strategy is insufficient to combat this, therefore combining different weed control techniques becomes a workable way to accomplish thorough weed control while also increasing cotton yield. Physical, mechanical, cultural, biological, and chemical methods are all included in integrated weed management.

k. Babu, [2024] presents the idea of weeds and examines their economic and ecological importance. It explores the traits that make them especially difficult to manage, how they interact with other species, and why they are frequently effective rivals in a variety of settings. The discussion of successful weed management techniques in agricultural and natural habitats will begin with this basic understanding of weeds.

Rathod Prajwal Ashok, [2024] the study was conducted in the Maharashtra state's Yavatmal area, where cotton is grown as a significant commercial crop. The purpose of the study was to investigate cotton's productivity and resource utilization as well as the disparity between input and output levels. Primary data on ninety cotton growers from the two tahsils of Pusad and Umarkhed in the Maharashtra district of Yavatmal served as the basis for the inquiry. The primary data was gathered in 2022–2023. According to the study, in order to increase cotton productivity on the sample farms, it is necessary to make the best use of human labor, machine power, manures, chemical fertilizers, and plant protection.

Bishan Singh, [2022] IWM is a type of weed control that has to be investigated more and more as a locally accessible, economically feasible, environmentally sustainable, and user-friendly method. The crop has significant losses in seed cotton production between 15 and 60 days after sowing, which is the critical time of crop-weed competition. Due to their competition for nutrients, moisture, light, and space, weeds are the main obstacles that lower crop yields. Depending on the type and severity of weeds in the field, cotton losses from weeds might range from 50 to 85 percent. The two methods that farmers most frequently use are intercultural operations and manual weeding.

Kishore Kumar P., [2022] In 2019 and 2020, an experiment was carried out at the Agricultural College and Research Institute in Madurai to investigate cotton weed control choices as influenced by different weed detecting techniques. The experiment was designed using a split plot and was repeated three times. Three weed identification methods—the manual approach (M1), image detection using a manually operated camera (M2), and image detection using a drone camera (Heli-cam) (M3)—were investigated as main plot treatments, along with eight weed control techniques as subplot treatments. The results of the experiment show that using a drone camera (M3) for image detection and applying a 75% dosage of Quizalofop ethyl 50 g a.i. ha-1 + Pyrithiobac Sodium 62.5 g a.i. ha-1 at 15 DAS as early post-emergence, followed by a post-emergence application of Fluazifop butyl 140 g a.i. ha-1 + Fenoxaprop ethyl 40 g a.i. ha-1 at 40 DAS, is the best way to control herbicide dosage and expense.

Lawrence Malinga, [2021] outlines the contribution that cotton production has had to global development, emphasizing how cotton helps the world's economy thrive, especially in South Africa. Cotton is one of the most valuable materials extensively utilized in the apparel industry and other products such as cotton swabs and cottonseed oil. Cotton accounted for around 75% of global fiber use in the early 1900s, but today it makes up less than 30%. In the middle of the 1990s, synthetic fibers took the lead. Among other things, water shortages, climate change, and pest issues contributed to the fall. Cotton is one of the most important cash crops in emerging nations, and its production has contributed significantly to economic progress in Africa. varied environmental, meteorological, and political circumstances can lead to varied practices and effects when cotton is grown.

Panjabrao Deshmukh Krishi Vidyapeeth, [2021] According to research, the relative humidity in the morning increased by roughly 20% in the early stages of crop growth and by roughly 30% in the later stages. Monsoon planting had a higher radiation intensity than late sowing, and the population density increased from 1,33,333 pl ha-1 to 1,66,666 pl ha-1. The crop that was sowed first had the highest thermal units (2107.7 D0). During monsoon sowing, the crop's thermal and radiation use efficiency was at its peak.

K. Nalini, [2019] The effectiveness of a new formulation of pre-emergence herbicide pendimethalin 38.7% on cotton growth and development with improved weed management in a cost-effective manner under irrigated conditions was investigated during the winter seasons of 2008–09 and 2009–10 at Eastern Block Farm, Tamil Nadu Agricultural University, Coimbatore. Pendimethalin 38.7% was tested at four different doses: 1.5, 2.0, 2.5, and 4.0 kg/ha. It was contrasted with pendimethalin 30% 1.0 kg/ha, power weeders, early post-emergence herbicide trifloxysulfuron, and hand weeding. The pre-emergence application of pendimethalin (38.7%) at 2.0 kg/ha at 3 days after seeding (DAS), followed by hand weeding and earthing at 45 DAS, did not exhibit any phytotoxic effects on cotton and resulted in lower biomass and weed density along with a 41.5% increase in seed cotton yield over unweeded control and higher net returns.

Nagaraju Navagana, [2017] In order to determine the weed flora, species composition, density, frequency, and importance value index (IVI), a survey of the weeds growing in cotton crop fields in the 43 mandals of Visakhapatnam district was conducted. Determine the species composition, density, frequency, significance value index (IVI), and weed flora. Phytosociological research findings showed that Poaceae and Cyperaceae came next. Phyllanthus debilis was discovered to be the most prevalent species, followed by Chromoleana odorata, Celosia argentea, Phyllanthus amarus, and Cyperus iria, according to the results of phytosociological investigations. The Value Indiex (IVI) of individual weed species found in cotton crop fields showed that Chenopodium album was the most significant species, followed in order by Euphorbia hirta, Phyllanthus maderaspatensis, Cleome viscosa, and Tridax procumbens.

Harphool Meena, [2017] An experiment on "Grassy Weed Management in Cotton under Humid Southern Plain Zone of Rajasthan" was carried out at the Agricultural Research Station in Banswara during the two consecutive kharifs of 2011 and 2012. With four replications and six treatments, the experiment was set up using a Randomized Block Design. The results showed that applying the post-emergence herbicide Pantera 4% EC @ 60g a.i. ha-1 produced considerably higher bolls plant-1 (29.06), boll weight (3.93g), and seed cotton yield (2065 kg ha-1). However, it was determined to be comparable to Quizalofap-P-Ethyl @ 50g a.i. ha-1 and weed free check. The application of post-emergence herbicide Pantera 4%EC @ 60g a.i. ha-1 resulted in the highest weed control efficiency (50.10 and 42.50%) at 30 and 60 DAS, the lowest weed population (16.50 and 19.98 m-2), weed dry matter accumulation (16.54 & 20.51g m-2) at 30 and 60 DAS, and the weed index (2.44 percent) compared to the other herbicide treatments.

Sudheesh Manalil, [2017] examines and summarizes the possible advantages of boosting crop competition as a weed control strategy. It also identifies research that needs to be done to guarantee the use of various tactics on a much larger scale. One strategy that could be included into the existing weed management systems is raising crop competitiveness. Some strategies to increase crop competitiveness over weeds include selecting cultivars with early vigor, using narrow row planting, aligning crop rows with respect to sunshine, and modifying planting density. A review of the literature on cotton reveals benefits for weed suppression by improving crop competitiveness through tight row spacing and increased planting density. In systems with low row spacing, early canopy closure would suppress a lot of problematic weeds.

A. Sathishkumar, [2016] review of research achievements in numerous domains relevant to this investigation that have been made at distinct locations. One of India's most significant commercial crops is cotton. Cotton grows very slowly in the early stages of its life cycle and has larger row spacing, which gives various types of weeds enough of room to develop and compete with it for nutrients and water. Weeds compete with crops for nutrients, moisture, light, and space, which is one of the main factors limiting agricultural yields. For broad-spectrum weed control and increased cotton productivity, integrating several weed management techniques would be a feasible solution. Thus, weed management has numerous characteristics such as physical, mechanical, cultural, chemical and integrated weed management approaches.

Kulvir Singh, [2016] An experiment was carried out in Kharif 2014 to assess the effectiveness of several herbicides for managing weeds and their impact on cotton crops. Weed-free plots had the highest seed cotton production (3.55 t/ha), followed by pyrithiobac-sodium 62.5 g/ha + quizalofop-ethyl 50 g/ha + one hoeing (3.52 t/ha) due to increased boll weight and quantity per plant. The weedy check had the statistically lowest yield (1.92 t/ha). Weed control efficiency (WCE) was lowest for weedy check (25.5%) and best under weed free check (90.3%), followed by pendimethalin 1.0 kg/ha + quizalofop-ethyl 50 g/ha + one hoeing (71.0%). Pyrithiobac-sodium 62.5 g/ha + quizalofop-ethyl 50 g/ha + one hoeing had the highest net returns (`100916/ha) and B:C ratio (2.14). Thus, this combination of pesticides and cultural techniques may be a workable strategy for economically viable and successful weed control in cotton.

Dhanalakshmi Ramachandra, [2016] Crop improvement has made extensive use of biotechnology. Currently, genetically modified (GM) crops are grown on over 2 billion hectares of land worldwide. Bt cotton was the first genetically modified crop to be introduced in India. Currently, 93% of all cotton land is planted with Bt cotton. But compared to other nations, the average yield is lower, indicating a chance to raise yield even more. Weed competition, which lowers production by 50 to 85%, is one of the main factors influencing yield. Adoption of transgenic herbicide-tolerant crops (HTCs) is part of Integrated Weed Management (IWM), which provides effective weed control. Soybean, cotton, corn, and canola are the main transgenic HTCs planted worldwide, and the yield gain brought about by efficient weed control is substantial. Glyphosate and glufosinate tolerant cotton systems have been successfully applied worldwide and are currently being tested in India. Herbicide-tolerant weeds may arise as a result of an over-reliance on a single MOA (mode of action) as opposed to a diversified IWM system with several complimentary herbicide MOAs. In order to control weeds in cotton sustainably, a variety of management techniques must be used.

A.N. Rao, [2015] carried out research on weeds and weed control in India. The effectiveness of herbicides is the main focus of research on weed control in India. Herbicides, whether used singly or in combination, have long been considered vital agents for controlling weeds in various ecosystems. IWM, which encompasses mechanical, cultural, chemical, biological, and preventative techniques, is recommended in aquatic and forest ecosystems as well as crop production systems. Herbicide-resistant (HR) transgenic crops have the potential to increase the effectiveness of weed control and promote the adoption of CA in India, so long as the dangers of these crops are thoroughly investigated before they are adopted and commercialized. In order to increase farmer profit while safeguarding the environment, new weed management strategies must be created that take into account the threat of HR weeds appearing in addition to the persistence and recurrence of weeds and the need to reduce weed management expenses.

Table 1 Comparative Table for Previous Research Done

Author (Year)	Key Findings	Major Outcome / Conclusion	Research Gap
A.N. Rao (2015)	Herbicide-centric weed research dominates; need for IWM	Integrated weed management (IWM) needed to reduce resistance and cost	Limited field-level validation of multi-component IWM systems
Dhanalakshmi Ramachandra (2016)	Weed competition reduces yield by 50–85%; HT crops useful but risky	Diversified herbicide MOAs and IWM essential	Long-term sustainability of HT crops under Indian conditions unclear
A. Sathishkumar (2016)	Weeds compete strongly due to slow early crop growth	Integration of weed control methods improves productivity	Lack of location-specific integrated protocols
Kulvir Singh (2016)	Herbicide combination + hoeing gave highest yield and WCE	Chemical + cultural integration is effective	Limited economic analysis across seasons and environments
Dhanalakshmi Ramachandra (2016)	Bt cotton dominant; yield still limited by weeds	Need diversified weed control strategies	Herbicide resistance evolution not fully addressed
A. Sathishkumar (2016)	Wider spacing encourages weed growth	IWM improves cotton productivity	Optimization of spacing + weed control interaction not well studied
Sudheesh Manalil (2017)	Crop competitiveness reduces weed pressure	Agronomic practices like narrow spacing help weed suppression	Limited varietal screening for weed competitiveness
Harphool Meena (2017)	Post-emergence herbicide improved yield and WCE	Herbicide application effective for grassy weeds	Need for integrated non-chemical alternatives
Nagaraju Navagana (2017)	Identified dominant weed flora and IVI patterns	Weed flora knowledge helps targeted control	Lack of dynamic seasonal weed succession data
K. Nalini (2019)	Pendimethalin + hand weeding increased yield significantly	Pre-emergence + manual weeding effective	Herbicide dose optimization under different soils not fully studied
PDKV (2021)	Environmental factors affect crop growth efficiency	Agronomic practices influence productivity	Weed-environment interaction poorly quantified
Lawrence Malinga (2021)	Cotton importance declining globally	Highlights need for sustainable production systems	Weed impact on global cotton sustainability under-studied
Bishan Singh (2022)	Critical weed period 15–60 DAS; major yield loss	Timely weed control is essential	Precision timing models for weed control limited
Kishore Kumar P. (2022)	Drone-based detection improves herbicide efficiency	Precision agriculture reduces chemical use	High cost and scalability of drone systems
K. Akhil (2024)	IWM is necessary due to weed competition	Multi-method weed control recommended	Lack of standardized IWM packages for regions
K. Babu (2024)	Weed ecology and competitiveness explained	Provides foundation for weed management strategies	Need for applied translation of ecological theory
Rathod Prajwal Ashok (2024)	Inefficient input use reduces cotton productivity	Input optimization improves yield	Weed-specific input efficiency not isolated
Aditi Agrawal (2025)	Preventive, cultural, mechanical, chemical methods reviewed	Integrated approach essential for cotton	Lack of comparative long-term field trials
K. Vasave J. B. (2025)	Weed-free plots reduce nutrient depletion significantly	Weed control improves NPK efficiency	Limited studies on nutrient dynamics under different weed regimes
Dhiman Mukherjee (2025)	Weed IVI varies across blocks; key dominant weeds identified	Site-specific weed control required	Lack of predictive weed community modeling under edaphic variation

Research Gap

Although various studies have been undertaken on weed flora and weed control in cotton ecosystems, there is little research on the comparative ecological analysis of weed distribution patterns using Raunkiaer's frequency classes in the cotton-growing regions of Shrirampur and Rahuri. Previous research has mostly concentrated on weed control strategies, herbicide efficacy, and yield losses, with relatively little attention paid to the ecological behavior, frequency distribution, and community structure of weeds under various agroecological circumstances. There is particularly little information available about the differences in weed dominance and species composition between these regions' irrigated and semi-arid cotton producing systems. Furthermore, the use of Raunkiaer's frequency class approach to assess the ecological stability and diversification of weed communities in cotton agroecosystems has not been fully studied. Therefore, a rigorous comparative study is required to understand regional weed dynamics and to design location-specific, sustainable weed management strategies for cotton agriculture.

Methodology

The present phytosociological study was carried out in two tehsils of Ahmednagar district: Shrirampur and Rahuri. Shrirampur tehsil includes 55 villages divided into four revenue mandals, whereas Rahuri tehsil has 96 villages divided into seven revenue mandals. The study focused solely on cotton crop fields during the Kharif season. For the phytosociological research of cotton weed flora, five cotton fields were randomly chosen from agriculturally relevant and representative villages in each revenue mandal in both tehsils. Thus, random quadrat sampling method was conducted mandal-wise to guarantee sufficient representation of the study area. The phytosociological investigation of weeds connected with cotton crops was conducted using a random quadrat sampling method. We employed a square-shaped quadrat composed of iron rods measuring 1 m × 1 m to sample the herbaceous weed growth. In each cotton field, 10 quadrats were randomly laid using a basic random quadrat sampling method. In Shrirampur tehsil, 4 mandals × 5 cotton fields × 10 quadrats equal 200 quadrats. In Rahuri Tehsil, 7 mandals x 5 cotton fields x 10 quadrats equal 350 quadrats. Thus, a total of 550 quadrats were tested for cotton crop phytosociology in both tehsils simultaneously.

The following materials were used during the field observations: GPS camera, iron-bar quadrat frame (1 × 1 m), rope and string, nails, measuring scale, field diary and notebook, pencil, pen, eraser, and stationery items. Within each quadrat, all weed species found in the cotton crop were identified and documented. Various phytosociological parameters were determined by counting the number of individuals in each weed species. The distribution and homogeneity of weed vegetation in cotton fields were determined using Raunkiaer's frequency classifications.

Table 2 Weed Vegetation in Cotton Fields

Frequency (%)	Frequency Class
0–20	A
21–40	B
41–60	C
61–80	D
81–100	E

Data Collection

In the Maharashtra regions of Rahuri and Shrirampur, a phytosociological investigation of weed flora was conducted. While phytosociological research was done between 2020 and 2022 utilizing the random quadrat sample approach, weed collecting was done between 2019 and 2025. A wide variety of dicotyledonous and monocotyledonous weeds were found in roadsides, wetland habitats, grasslands, wastelands, and agricultural regions, according to the study. The following weeds, which are listed in the table below, were among the weeds found during the investigation.

Table 3 Data Collection of cotton weeds in Rahiuri and Shrirampur regions

Abelmoschus ficulneus	*Abutilon indicum*	*Acalypha indica*	*Acalypha malabarica*
Acanthospermum hispidum	*Achyranthes aspera*	*Acrachne racemosa*	*Ageratum conyzoides*
Alternanthera sessilis	*Alysicarpus bupleurifolius*	*Alysicarpus scariosus*	*Alysicarpus vaginalis*
Amaranthus hybridus	*Amaranthus polygonoides*	*Amaranthus spinosus*	*Amaranthus viridis*
Ammannia baccifera	*Bidens pilosa*	*Boerhavia diffusa*	*Boerhavia erecta*
Calyptocarpus vialis	*Cardiospermum halicacabum*	*Celosia argentea*	*Cenchrus ciliaris*
Chloris barbata	*Chloris virgata*	*Cleome viscosa*	*Clitoria ternatea*
Commelina benghalensis	*Commelina diffusa*	*Commelina forskaolii*	*Convolvulus arvensis*
Corchorus olitorius	*Corchorus trilocularis*	*Crotalaria hebecarpa*	*Crotalaria juncea*
Cucumis maderaspatanus	*Cucumis melo*	*Cyanthillium cinereum*	*Cyanotis axillaris*
Cyanotis fasciculata	*Cynodon dactylon*	*Cyperus compressus*	*Cyperus difformis*
Cyperus esculentus	*Cyperus iria*	*Cyperus pumilus*	*Cyperus rotundus*
Dactyloctenium aegyptium	*Datura innoxia*	*Desmodium dichotomum*	*Dichanthium annulatum*
Dicliptera paniculata	*Digera muricata*	*Digitaria bicornis*	*Digitaria ciliaris*
Dinebra retroflexa	*Echinochloa colona*	*Eclipta prostrata*	*Eleusine indica*
Eragrostis ciliaris	*Eragrostis minor*	*Eragrostis tenella*	*Eragrostis unioloides*
Eragrostis viscosa	*Euphorbia heterophylla*	*Euphorbia hirta*	*Euphorbia hypericifolia*
Euphorbia parviflora	*Euphorbia thymifolia*	*Evolvulus alsinoides*	*Gomphrena celosioides*
Heteropogon contortus	*Hibiscus panduriformis*	*Indigofera cordifolia*	*Indigofera hochstetteri*
Ipomoea biflora	*Ipomoea eriocarpa*	*Ipomoea triloba*	*Lagascea mollis*
Lantana camara	*Launaea procumbens*	*Leucas aspera*	*Leucas longifolia*

Leucas martinicensis	*Leucas urticifolia*	*Malvastrum coromandelianum*	*Martynia annua*
Melanocenchris jacquemontii	*Merremia emarginata*	*Moorochloa eruciformis*	*Oldenlandia corymbosa*
Oldenlandia herbacea	*Oxalis corniculata*	*Panicum repens*	*Parthenium hysterophorus*
Paspalum distichum	*Pavonia zeylonica*	*Phyllanthus amarus*	*Phyllanthus maderaspatensis*
Physalis angulata	*Polygala arvensis*	*Polygala erioptera*	*Portulaca oleracea*
Portulaca quadrifida	*Psoralea corylifolia*	*Rhynchosia minima*	*Ricinus communis*
Senna tora	*Setaria intermedia*	*Setaria verticillata*	*Sida acuta*
Sida cordata	*Sida spinosa*	*Solanum americanum*	*Solanum nigrum*
Solanum villosum	*Solanum virginianum*	*Sonchus asper*	*Spermacoce articularis*
Tephrosia pumila	*Teramnus mollis*	*Tetrapogon tenellus*	*Trianthema portulacastrum*
Trichodesma indicum	*Trichodesma zeylanicum*	*Tridax procumbens*	*Triumfetta rhomboidea*
Triumfetta rotundifolia	*Urochloa panicoides*	*Urochloa ramosa*	*Urochloa reptans*
Vigna trilobata	*Xanthium strumarium*		

Formulas used

The following phytosociological attributes were calculated using standard ecological methods.

1. Absolute Frequency (AF)

AF=No of quadats in which speceis occured /Total no of qudrats studiedX 100 ………………………………… [4.1.]

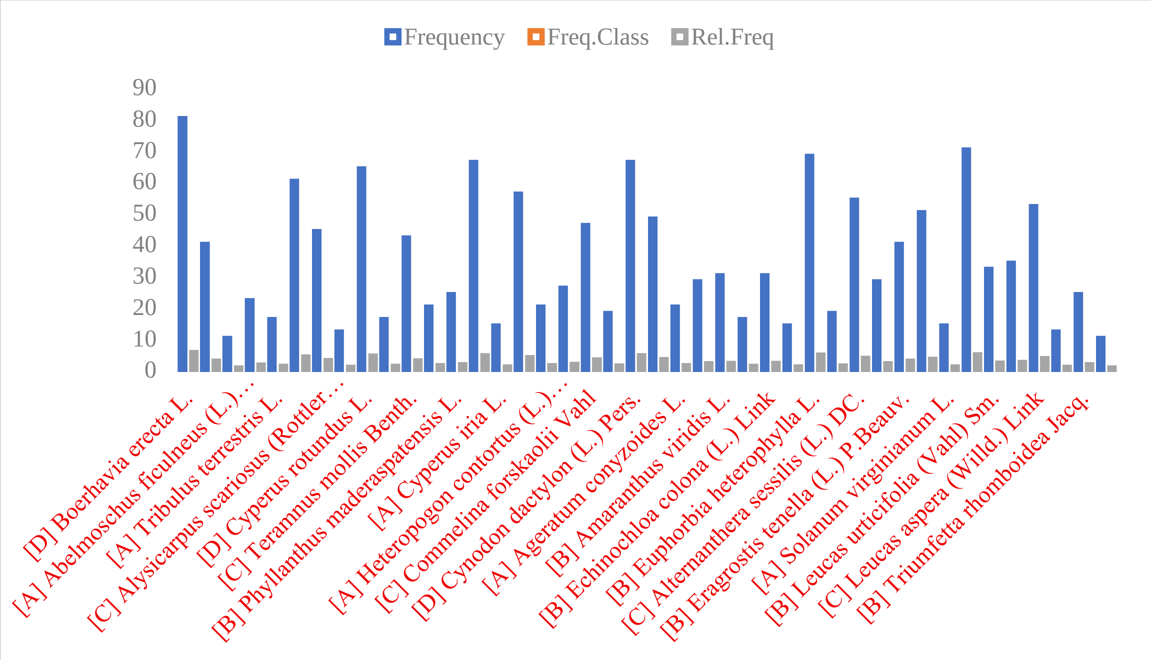
2. Relative Frequency (RF)

RF=Absolute value of a species/sum of absolute frequency values of all the species x100 …… [4.2.]

The structure, distribution, and ecological condition of weed species linked to cotton crops in both tehsils were ascertained by analyzing the recorded data. Conclusions about the makeup and behavior of weed flora in cotton agroecosystems were made using computed phytosociological parameters and frequency classes.

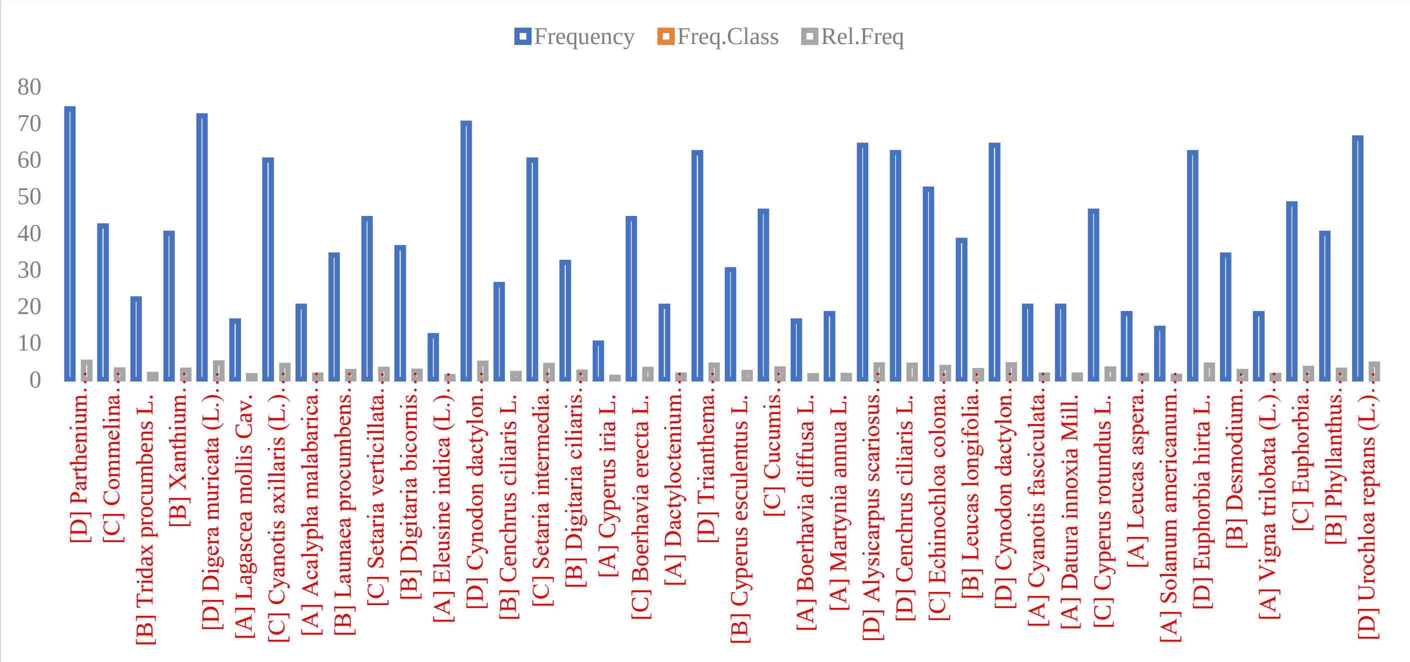
Results

A great diversity of weed flora with significant variation in species composition, frequency, and abundance among different mandals was found in the phytosociological research of cotton fields in Shrirampur and Rahuri tehsils. Shrirampur mandal identified 42 weed species in Shrirampur tehsil, totaling 1439 individuals and a cumulative frequency of 1454. Parthenium hysterophorus (70% frequency), Euphorbia heterophylla (68% frequency), Setaria verticillata, and Cynodon dactylon (66% each) were the most common weeds, demonstrating a high degree of adaptation to cotton agroecosystems. Additionally, species with high frequency and relative frequency values were Boerhavia erecta, Cyperus rotundus, and Moorochloa eruciformis.



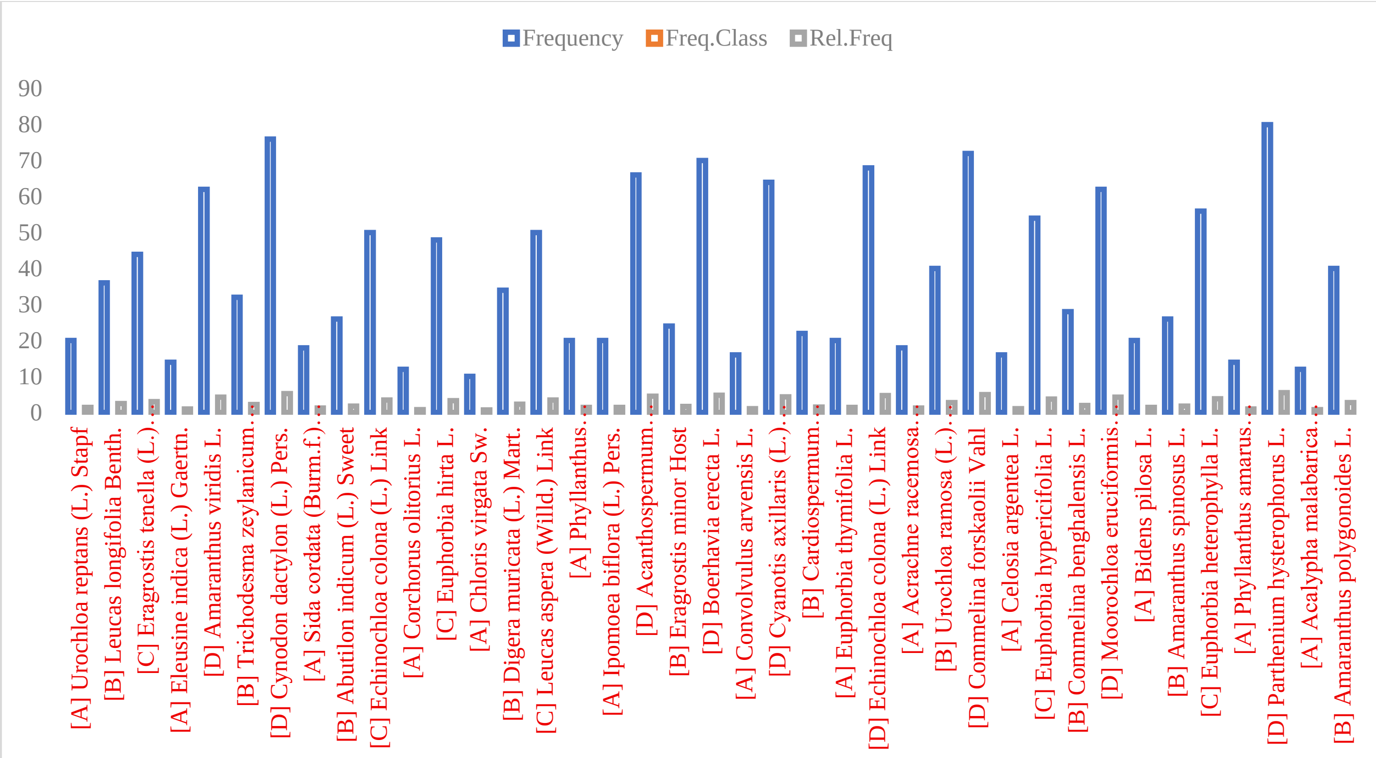
Graph 1 Plant - Cotton Shrirampur Tehsil Shrirampur Mandal

The cotton field's phytosociological research revealed 42 weed species with 1439 individuals spread across 50 quadrats, demonstrating the study area's significant weed variety and robust weed establishment. Parthenium hysterophorus, Cynodon dactylon, Setaria verticillata, Cyperus rotundus, and Euphorbia heterophylla were the predominant weed species in cotton crop areas, as evidenced by their high frequency and relative frequency values. Parthenium hysterophorus recorded the highest frequency (70%) and relative frequency (4.81%), followed by Euphorbia heterophylla (68%), Setaria verticillata and Cynodon dactylon (66%), and Cyperus rotundus (64%), showing their strong adaptability under existing agro-climatic conditions. Most dominant weeds belonged to frequency classes C and D, reflecting stable establishment and greater ecological success in cotton fields. In contrast, species such as Abelmoschus ficulneus, Abutilon indicum, and Pavonia zeylonica showed low frequency and poor distribution, indicating limited occurrence and weaker competitive ability. Overall, the study shows that invasive grasses, sedges, and broad-leaved weeds predominate in cotton fields, causing intense crop-weed competition that could negatively impact cotton yield and growth.



Graph 2 Plant - Cotton Shrirampur Tehsil Belapur Mandal

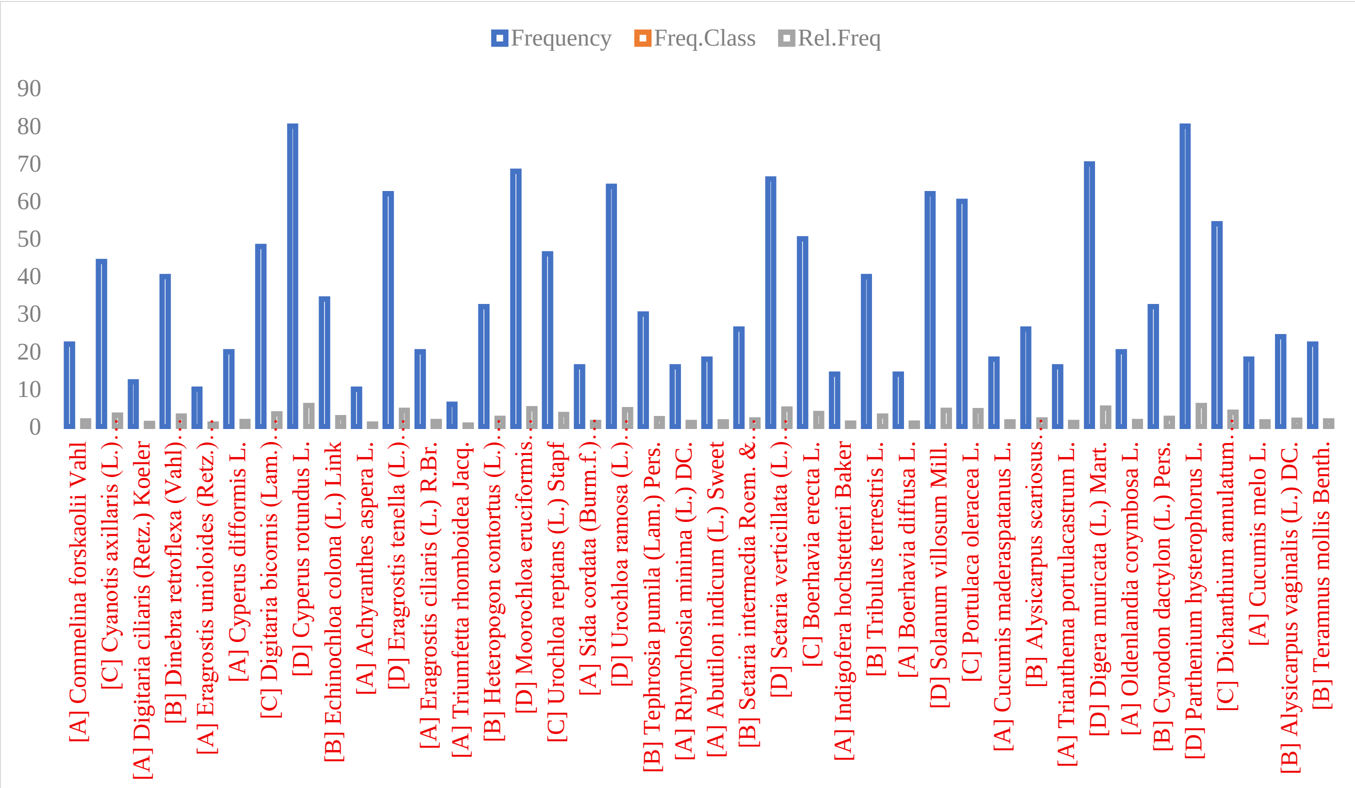
Parthenium hysterophorus, Digera muricata, Urochloa reptans, and Cynodon dactylon were the most prevalent of the 40 weed species found in Belapur Mandal, with 1419 individuals and a total frequency of 1572. In cotton fields, the abundance of broad-leaved weeds and perennial grasses indicated fierce weed competition. Parthenium hysterophorus, Digera muricata, Cynodon dactylon, Urochloa reptans, Alysicarpus scariosus, Trianthema portulacastrum, and Euphorbia hirta were the predominant weed species in cotton crop fields. These species displayed high frequency and relative frequency values, indicating greater density, abundance, and dominance. The highest frequency (74%) and relative frequency (4.71%) were recorded by Parthenium hysterophorus, followed by Digera muricata (72%), Cynodon dactylon (70%), and Urochloa reptans (66%), indicating their excellent adaptability and invasive character under the current agroclimatic conditions. In cotton fields, the majority of dominant weeds were found in frequency classes C and D, which indicate their widespread dispersion, stable establishment, and successful colonization. Sedges were less common than grasses and broad-leaved weeds, indicating intense competition between crops and weeds for nutrients, moisture, light, and space. Cyperus iria, Eleusine indica, Solanum americanum, and Boerhavia diffusa, on the other hand, exhibited low frequency and restricted occurrence, suggesting weak adaptability and reduced competitive potential. Overall, the study shows that the cotton ecosystem is dominated by invasive and highly adaptable weeds, which could drastically lower cotton productivity if integrated weed management techniques are not used.



Graph 3 Plant - Cotton Shrirampur Tehsil Taklibhan Mandal

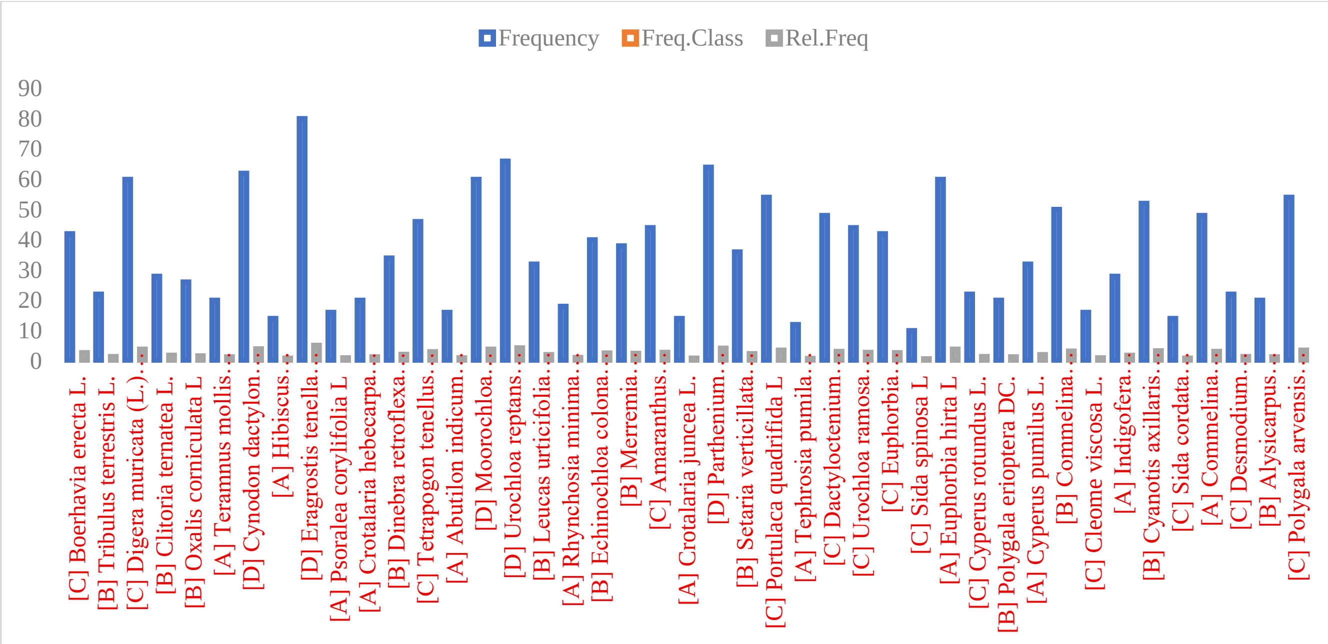
39 species with 1189 individuals and a cumulative frequency of 1460 were found in Taklibhan Mandal. Acanthospermum hispidum, Cynodon dactylon, Commelina forskaolii, Boerhavia erecta, and Parthenium hysterophorus displayed the highest frequency (80%), suggesting a significant prevalence of invasive and resistant weed flora. Parthenium hysterophorus, Cynodon dactylon, Commelina forskaolii, Boerhavia erecta, Acanthospermum hispidum, Cyanotis axillaris, and Echinochloa colona were the predominant weed species in cotton crop fields. These species displayed high frequency and relative frequency values, indicating greater density, abundance, and dominance. Due to their strong adaptability and invasive nature under the current agroclimatic conditions, Parthenium hysterophorus recorded the highest frequency (80%) and relative frequency (5.48%), followed by Cynodon dactylon (76%), Commelina forskaolii (72%), Boerhavia erecta (70%), and Echinochloa colona (68%).

Frequency classifications C and D included the majority of dominant weeds, demonstrating their widespread dispersion and permanent establishment in cotton fields. Sedges were less common than grasses and broad-leaved weeds, indicating fierce competition between crops and weeds for nutrients, water, light, and space. Conversely, species including Eleusine indica, Acalypha malabarica, Corchorus olitorius, and Chloris virgata had limited occurrence and low frequency, suggesting a lack of adaptability and competitiveness. Overall, the study emphasizes how invasive and fiercely competitive weed flora predominate in cotton ecosystems, which could have a negative impact on cotton yield if appropriate integrated weed control techniques are not used.



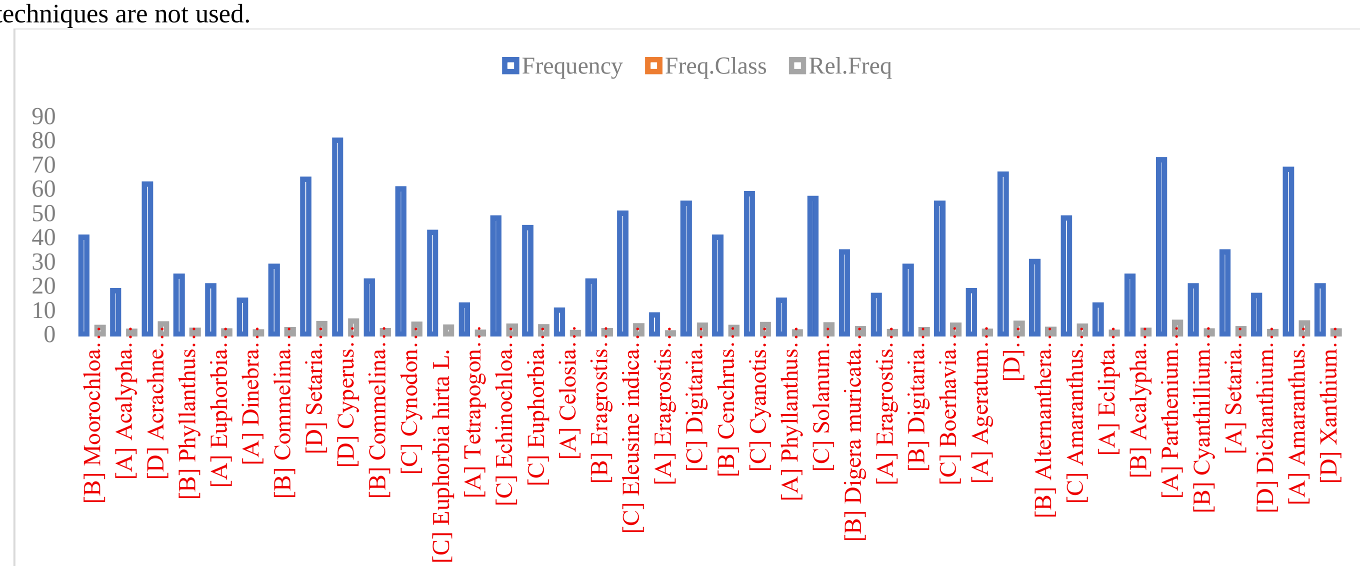
Graph 4 Plant - Cotton Shrirampur Tehsil Undirgaon Mandal

Undirgaon Mandal recorded 40 species, 1341 individuals, and 1410 cumulative frequency. Cyperus rotundus and Parthenium hysterophorus were the most common weeds (80% frequency each), followed by Digera muricata, Moorochloa eruciformis, and Setaria verticillata. The prevalence of sedges and grasses in this area suggested that monocot weeds thrived. Parthenium hysterophorus, Cyperus rotundus, Digera muricata, Moorochloa eruciformis, Setaria verticillata, Urochloa ramosa, Eragrostis tenella, and Solanum villosum were the dominant weed species, with high frequency and relative frequency values indicating higher density, abundance, and dominance in cotton crop fields. Parthenium hysterophorus and Cyperus rotundus had the highest frequency (80%) and relative frequency (5.67%), followed by Digera muricata (70%), Moorochloa eruciformis (68%), and Setaria verticillata (66%), indicating their high adaptability and invasiveness under current agro-climatic conditions. Most prominent weeds were in frequency classes C and D, indicating widespread dispersion, permanent establishment, and successful colonization in cotton fields. Grasses, sedges, and broad-leaved weeds were abundant, indicating intense crop-weed competition for nutrients, water, light, and space. In contrast, species such as Triumfetta rhomboidea, Eragrostis unioloides, Achyranthes aspera, and Digitaria ciliaris had low frequency and restricted occurrence, indicating weak adaptability and reduced competitive ability. Overall, the study emphasizes the dominance of invasive and highly competitive plant flora in cotton ecosystems, which may negatively affect cotton growth and productivity if effective integrated weed management strategies are not used.



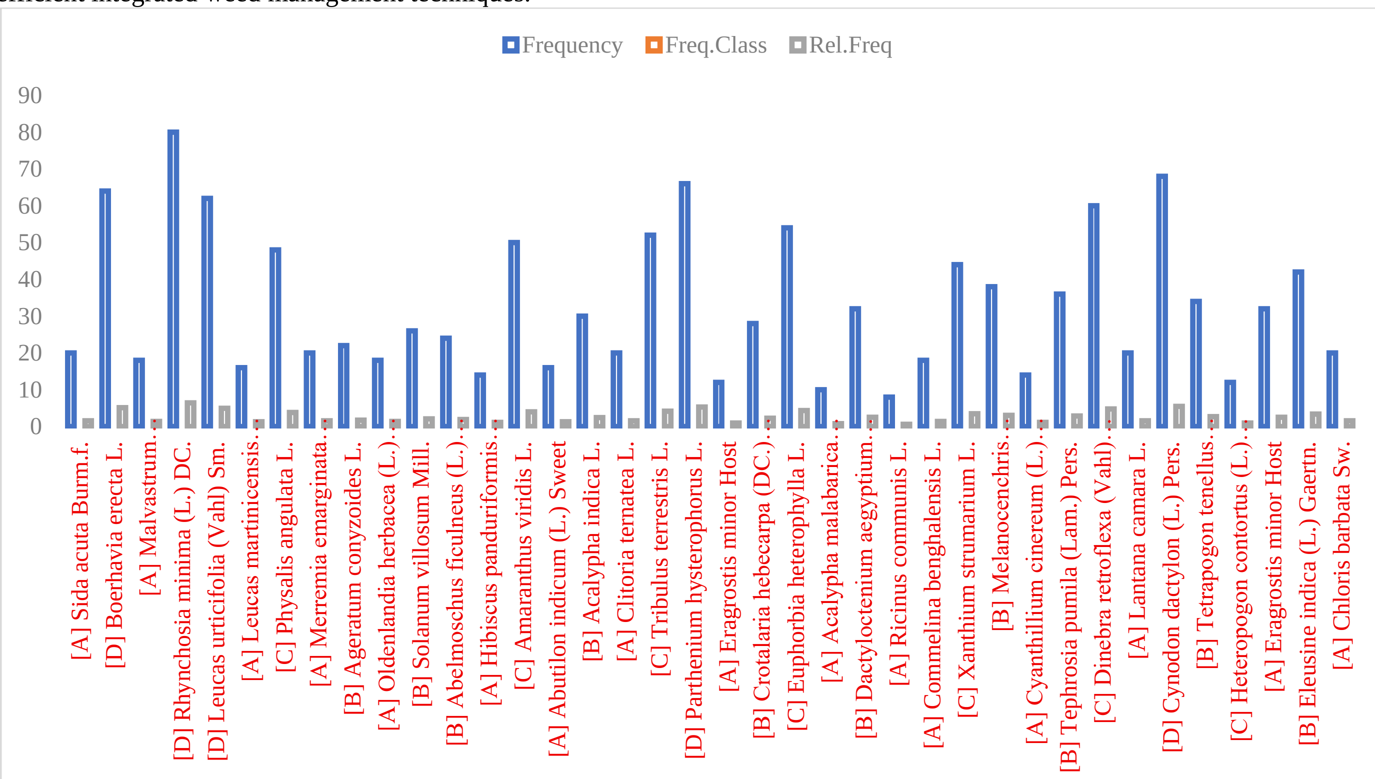
Graph 5 Plant - Cotton Rahuri Tehesil Rahuri Mandal

Rahuri Mandal identified 43 weed species with 1388 individuals and a cumulative frequency of 1546 in Rahuri Tehsil. With an 80% frequency, Eragrostis tenella was found to be the most prevalent species, followed by Digera muricata, Urochloa reptans, Parthenium hysterophorus, and Cynodon dactylon. Eragrostis tenella, Urochloa reptans, Parthenium hysterophorus, Cynodon dactylon, Digera muricata, Moorochloa eruciformis, and Euphorbia hirta were the predominant weed species in cotton crop fields. These species showed high frequency and relative frequency values, indicating greater density, abundance, and dominance. The highest frequency (80%) and relative frequency (5.17%) were reported by Eragrostis tenella, followed by Urochloa reptans (66%), Parthenium hysterophorus (64%), and Cynodon dactylon (62%). These results demonstrate the species' remarkable adaptability and competitiveness under the current agroclimatic conditions. Frequency classifications C and D included the majority of dominant weeds, demonstrating their widespread dispersion and permanent establishment in cotton fields. Sedges were less common than grasses and broad-leaved weeds, indicating intense competition between crops and weeds for nutrients, moisture, light, and space. Conversely, species with limited distribution and low frequency, as Sida spinosa, Tephrosia pumila, Hibiscus panduriformis, and Crotalaria juncea, shown less adaptation and competitiveness. Overall, the study emphasizes how invasive and fiercely competitive weed species predominate in cotton ecosystems, which could drastically lower cotton yield if appropriate integrated weed control techniques are not used.



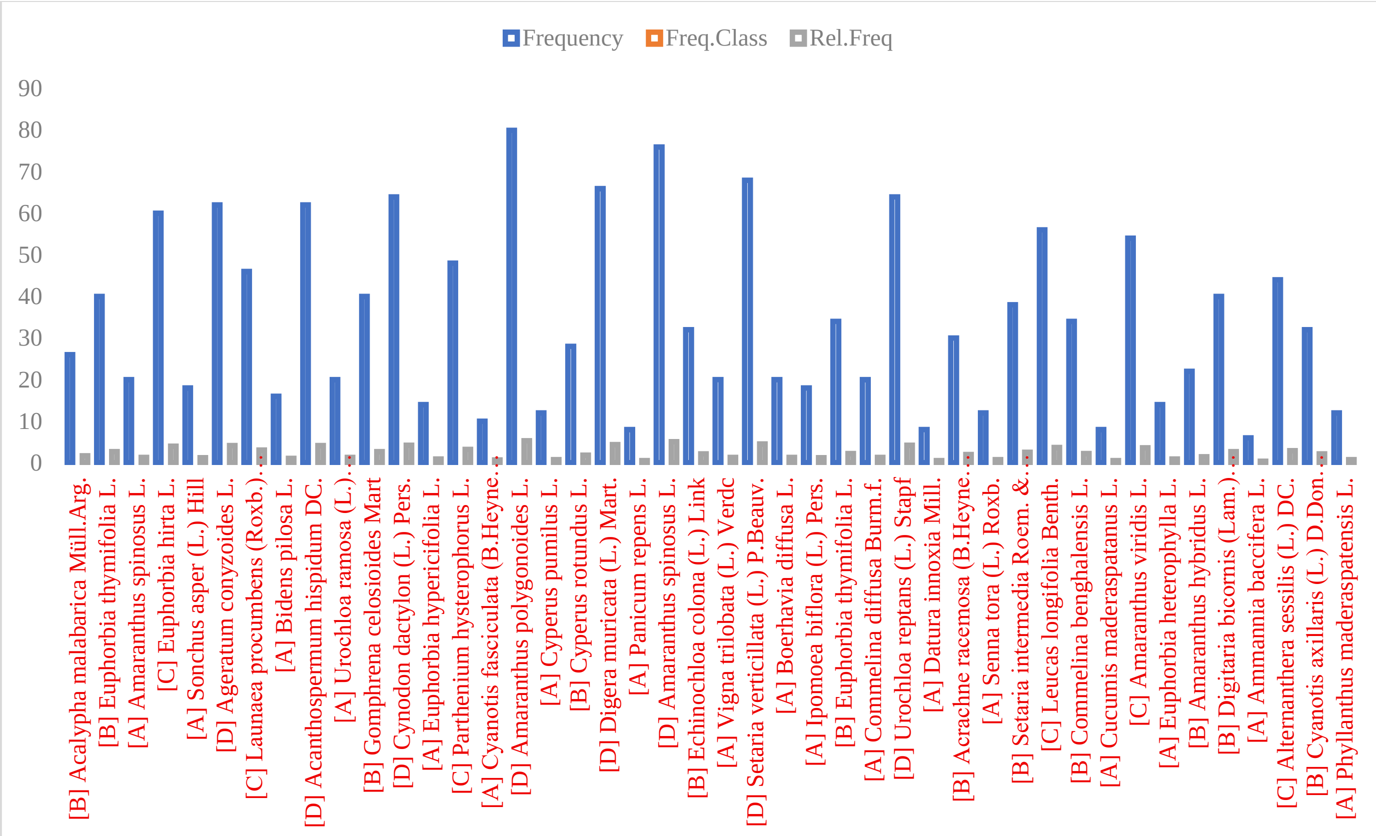
Graph 6 Plant - Cotton Rahuri Tehesil Satral Mandal

Satral Mandal recorded 40 species, 1225 individuals, and a cumulative frequency of 1450. Amaranthus hybridus, Acanthospermum hispidum, Parthenium hysterophorus, and Cyperus rotundus (80% frequency) were all very common in this area. Parthenium hysterophorus, Cyperus rotundus, Amaranthus hybridus, Acanthospermum hispidum, Setaria intermedia, Acrachne racemosa, and Cynodon dactylon were the predominant weed species in cotton crop fields. These species showed high frequency and relative frequency values, indicating greater density, abundance, and dominance. The highest frequency (72%) and relative frequency (4.97%) were observed by Parthenium hysterophorus, followed by Cyperus rotundus (80%), Amaranthus hybridus (68%), and Acanthospermum hispidum (66%), indicating their excellent adaptation and invasive nature under the current agroclimatic conditions. In cotton fields, the majority of dominant weeds were found in frequency classes C and D, which indicate their widespread dispersion, stable establishment, and successful colonization. The high representation of grasses, sedges, and broad-leaved weeds indicates fierce competition between crops and weeds for nutrients, moisture, light, and space. On the other hand, species including Eragrostis viscosa, Celosia argentea, Tetrapogon tenellus, and Phyllanthus amarus exhibited low frequency and restricted occurrence, suggesting less adaptability and a lower capacity for competition. Overall, the study emphasizes how invasive and fiercely competitive weed flora predominate in cotton ecosystems, which could drastically lower cotton yield in the absence of efficient integrated weed management techniques.



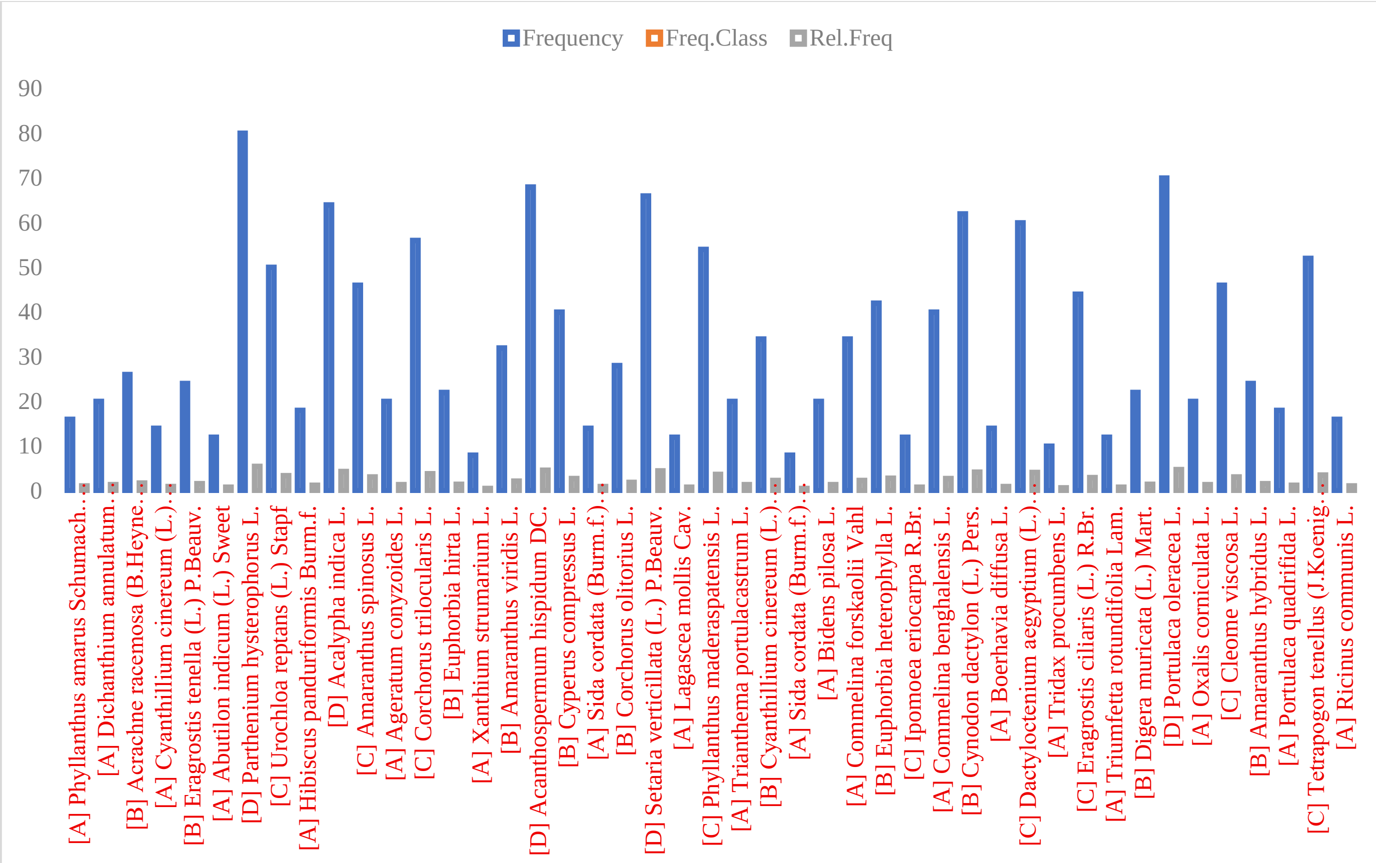
Graph 7 Plant - Cotton Rahuri Tehesil Taharabad Mandal

Taharabad mandal revealed considerably lower weed density with 1047 individuals and 1248 cumulative frequency across 38 species. The prominent species were Rhynchosia minima, Cynodon dactylon, Parthenium hysterophorus, and Boerhavia erecta. Parthenium hysterophorus, Cyperus rotundus, Rhynchosia minima, Boerhavia erecta, Leucas urticifolia, Cynodon dactylon, and Euphorbia heterophylla were the predominant weed species in cotton crop fields. These species displayed high frequency and relative frequency values, indicating greater density, abundance, and dominance. The highest frequency (66%) and relative frequency (5.29%) were observed by Parthenium hysterophorus, followed by Cynodon dactylon (68%), Rhynchosia minima (80%), and Boerhavia erecta (64%), indicating their excellent adaptation and invasive behavior under the current agroclimatic conditions. In cotton fields, the majority of dominant weeds were found in frequency classes C and D, which indicate their widespread dispersion, stable establishment, and successful colonization. The high representation of grasses, sedges, and broad-leaved weeds suggests that cotton faces fierce competition for nutrients, water, light, and space. On the other hand, species including Acalypha malabarica, Eragrostis minor, Ricinus communis, and Heteropogon contortus exhibited low frequency and restricted occurrence, suggesting inadequate adaptability and a lower capacity for competition. Overall, the study shows that cotton agro-ecosystems are dominated by invasive and fiercely competitive weed species, which could drastically lower crop output unless efficient integrated weed management techniques are implemented.



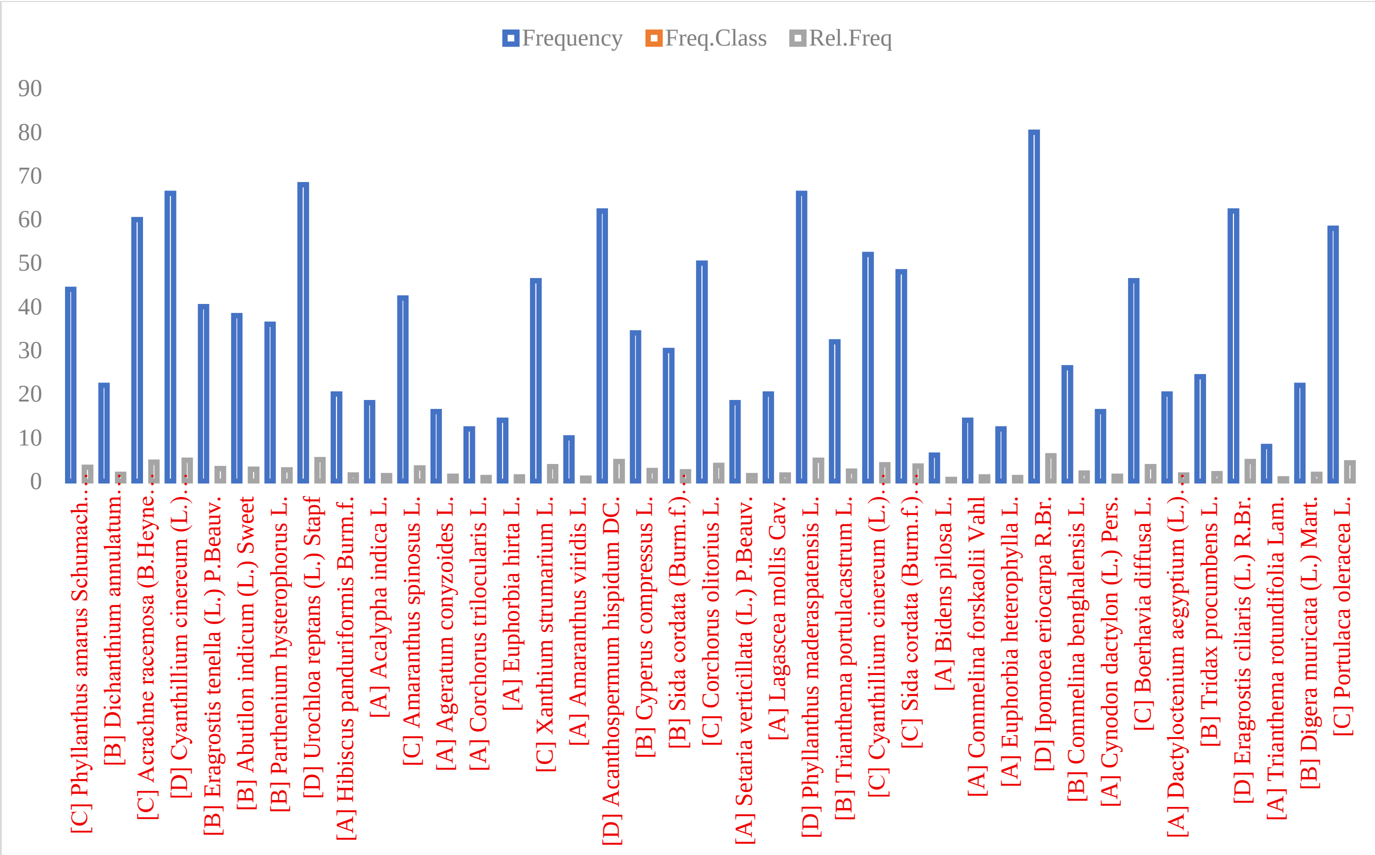
Graph 8 Plant - Cotton Rahuri Tehesil Deolali Pravara Mandal

In Deolali Pravara mandal, 44 weed species were found, with 1328 individuals and a cumulative frequency of 1502. Amaranthus polygonoides had the greatest frequency (80%), followed by Amaranthus spinosus, Setaria verticillata, Digera muricata, and Cynodon dactylon. The dominant weed species in cotton crop fields were Parthenium hysterophorus, Cynodon dactylon, Amaranthus polygonoides, Digera muricata, Setaria verticillata, Urochloa reptans, Ageratum conyzoides, and Acanthospermum hispidum, all of which had high frequency and relative frequency values, indicating greater density, abundance, and dominance. Amaranthus polygonoides had the highest frequency (80%) and relative frequency (5.33%), followed by Amaranthus spinosus (76%), Digera muricata (66%), and Cynodon dactylon (64%), indicating their excellent adaptation and invasive nature under the current agro-climatic conditions. Most prominent weeds were in frequency classes C and D, indicating widespread dispersion, permanent establishment, and successful colonization in cotton fields. Grasses and broad-leaved weeds were more common than sedges, indicating intense crop-weed competition for nutrients, water, light, and space. Ammannia baccifera, Panicum repens, Datura innoxia, and Cyanotis fasciculata, on the other hand, exhibited low frequency and restricted occurrence, showing a lack of competitive aptitude and adaptability. Overall, the study emphasizes the dominance of invasive and highly competitive weed flora in cotton ecosystems, which could drastically lower crop output unless effective integrated weed management measures are used.



Graph 9 Plant - Cotton Rahuri Tehesil Taklimiya Mandal

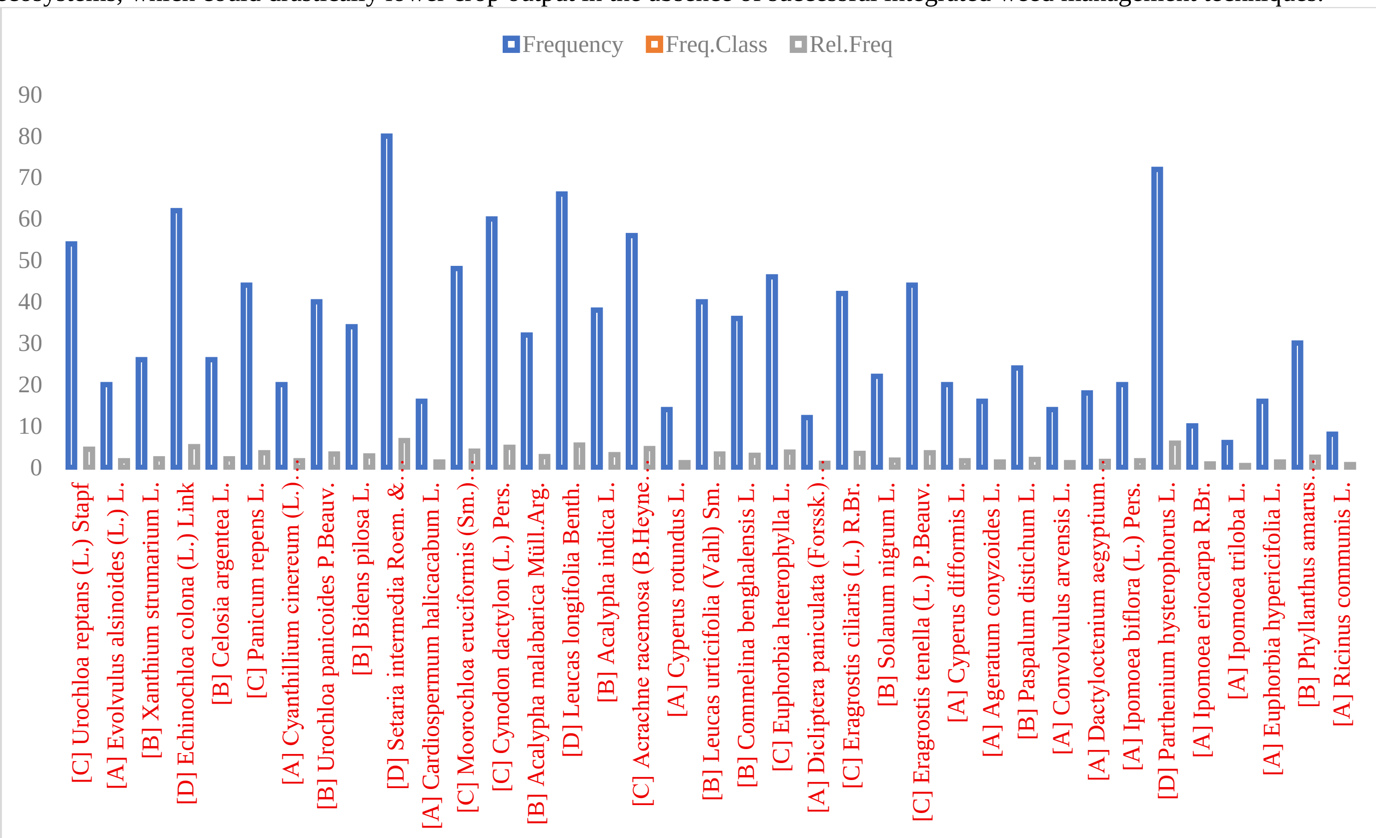
Taklimiya mandal recorded 45 weed species, totaling 1261 individuals and 1470 cumulative frequency. The dominant weeds were Parthenium hysterophorus, Portulaca oleracea, Acanthospermum hispidum, and Setaria verticillata. Parthenium hysterophorus, Cynodon dactylon, Acanthospermum hispidum, Setaria verticillata, Portulaca oleracea, Acalypha indica, and Urochloa reptans were the most common weed species in cotton crop fields, with high frequency and relative frequency values indicating higher density, abundance, and dominance. Parthenium hysterophorus had the highest frequency (80%) and relative frequency (5.44%), followed by Cynodon dactylon (62%), Acanthospermum hispidum (68%), and Portulaca oleracea (70%), indicating their excellent adaptation and invasive nature under the current agro-climatic conditions. Most prominent weeds were in frequency classes C and D, indicating widespread dispersion, permanent establishment, and successful colonization in cotton fields. Grasses, sedges, and broad-leaved weeds were abundant, indicating significant crop-weed competition for nutrients, water, light, and space. Tridax procumbens, Ipomoea eriocarpa, Sida cordata, and Xanthium strumarium, on the other hand, exhibited low frequency and restricted occurrence, showing a lack of competitive aptitude and adaptation. Overall, the study emphasizes the dominance of invasive and highly competitive weed flora in cotton ecosystems, which could drastically lower crop output unless efficient integrated weed control strategies are employed.



Graph 10 Plant - Cotton Rahuri Tehesil Brahamni Mandal

Brahamni mandal reported 39 species with 1132 individuals and 1358 cumulative frequency, with Eragrostis tenella having the highest frequency (80%), followed by Euphorbia hirta, Phyllanthus maderaspatensis, and Eleusine indica. Parthenium hysterophorus, Cynodon dactylon, Eragrostis tenella, Euphorbia heterophylla, Eleusine indica, Phyllanthus maderaspatensis, and Launaea procumbens were the dominant weed species, with high frequency and relative frequency values indicating higher density, abundance, and dominance in cotton crop fields. The highest frequency (80%) and relative frequency (5.89%) were observed by Eragrostis tenella, followed by Cynodon dactylon (46%), Launaea procumbens (62%), and Parthenium hysterophorus (48%), indicating their excellent adaptability and invasive character under the current agroclimatic conditions. In cotton fields, the majority of dominant weeds were found in frequency classes C and D, which indicate their widespread dispersion, stable establishment, and successful colonization. The high representation of grasses, sedges, and broad-leaved weeds indicates intense competition between crops and weeds for nutrients, moisture, light, and space. Conversely, species with low frequency and restricted occurrence, such as Cenchrus ciliaris, Celosia argentea, Cardiospermum halicacabum, and Crotalaria juncea, shown limited adaptability and a lower capacity for competition. Overall, the study emphasizes how invasive and fiercely competitive weed flora predominate in cotton ecosystems, which could drastically lower crop output in the absence of efficient integrated weed management techniques.

Setaria intermedia (80%), Parthenium hysterophorus, Leucas longifolia, and Echinochloa colona dominated the 37 species that Vambori Mandal reported with 1120 individuals and 1232 cumulative frequency. Parthenium hysterophorus, Cyperus rotundus, Setaria intermedia, Leucas longifolia, Cynodon dactylon, Echinochloa colona, and Urochloa reptans were the predominant weed species in cotton crop fields. These species showed high frequency and relative frequency values, indicating greater density, abundance, and dominance. The highest frequency (72%) and relative frequency (5.84%) were observed by Parthenium hysterophorus, followed by Setaria intermedia (80%), Leucas longifolia (66%), and Cynodon dactylon (60%), indicating their excellent adaptation and invasive nature under the current agroclimatic conditions. In cotton fields, the majority of dominant weeds were found in frequency classes C and D, which indicate their widespread dispersion, stable establishment, and successful colonization. The high representation of grasses, sedges, and broad-leaved weeds indicates intense competition between crops and weeds for nutrients, moisture, light, and space. On the other hand, species like Dicliptera paniculata, Ipomoea triloba, Ricinus communis, and Cyperus rotundus exhibited low frequency and restricted occurrence, suggesting limited adaptability and a lower capacity for competition. Overall, the study emphasizes how invasive and fiercely competitive weed flora predominate in cotton ecosystems, which could drastically lower crop output in the absence of successful integrated weed management techniques.



Graph 11 Plant - Cotton Rahuri Tehesil Vambori Mandal

Overall, the analysis showed that the majority of mandals in both tehsils were regularly dominated by invasive weeds, including Parthenium hysterophorus, Cynodon dactylon, Cyperus rotundus, Setaria spp., and Digera muricata. The predominant weed flora in cotton fields was made up of grasses and broad-leaved weeds, indicating intense competition for moisture, nutrients, and space. The prevalence of D and C frequency classes in a number of mandals is indicative of these weeds' broader dispersion and stable establishment under the current agroclimatic conditions. The findings demonstrate the need for efficient integrated weed control techniques in cotton farming in order to reduce weed infestation and increase crop yield.

Conclusion

Rich weed variety and significant variation in weed composition among several mandals were found in the phytosociological research of cotton fields in the tehsils of Shrirampur and Rahuri. The analysis of 550 quadrats revealed a significant concentration of broad-leaved weeds, sedges, and grasses. With 1439 individuals, Shrirampur mandal had the most weed species (42) in the Shrirampur tehsil, while Belapur mandal had the greatest cumulative frequency (1572). Parthenium hysterophorus, Cynodon dactylon, Setaria verticillata, Cyperus rotundus, and Digera muricata were the predominant weeds. Parthenium hysterophorus and Cyperus rotundus displayed extremely high frequencies (80%) in Taklibhan and Undirgaon mandals, demonstrating their strong adaptability and invasive behavior.

Deolali Pravara and Taklimiya mandals in Rahuri tehsil had the highest weed diversity, with 44 and 45 species, respectively. In several mandals, the predominant weeds were Eragrostis tenella, Parthenium hysterophorus, Setaria intermedia, Amaranthus polygonoides, and Cynodon dactylon. In cotton fields, the majority of dominant weeds belonged to frequency classes C and D, exhibiting a broad distribution and stable establishment. In both tehsils, invasive plants such Digera muricata, Setaria spp., Cynodon dactylon, Cyperus rotundus, and Parthenium hysterophorus were generally dominant. They are in fierce rivalry with cotton crops for nutrients, water, light, and space, as evidenced by their high frequency and relative frequency values.

According to the study, the cotton fields in the tehsils of Shrirampur and Rahuri have a varied and well-established weed flora, with grasses and broad-leaved weeds predominating. The most prevalent and extensively dispersed weeds were species like Parthenium hysterophorus, Cynodon dactylon, Cyperus rotundus, Setaria spp., and Eragrostis tenella. Under the current agroclimatic circumstances, stable weed establishment is indicated by the predominance of C and D frequency classes. Through fierce crop-weed competition, these weeds may have a major impact on cotton output. Thus, sustainable cotton farming and increased output require efficient integrated weed management techniques.

Future Scope

In cotton crop fields, the study found that invasive weeds like Parthenium hysterophorus, Cynodon dactylon, Cyperus rotundus, Setaria spp., Digera muricata, and Eragrostis tenella showed high frequency, density, abundance, and dominance, demonstrating their strong adaptability and competitive nature under the current agroclimatic conditions. In order to comprehend variations in weed composition, density, abundance, and dominance patterns under various environmental situations, future study should concentrate on seasonal and long-term monitoring of weed flora. To assess how soil properties, rainfall, irrigation techniques, temperature, and cropping methods affect weed dispersion and establishment, in-depth ecological studies may be carried out. To evaluate the effects of dominant weeds on nutrient intake, soil moisture, light availability, and cotton production reduction, more research on crop–weed competition is required. The ongoing use of herbicides in cotton farming may also make research on herbicide resistance in dominant weed species crucial. The creation of environmentally friendly integrated weed management techniques utilizing chemical, mechanical, biological, and cultural approaches for long-term weed control is also included in the future scope. Investigating biological control agents may offer environmentally safe management techniques, particularly when it comes to invasive weeds like Parthenium hysterophorus. Furthermore, for accurate weed identification and monitoring in cotton ecosystems, contemporary technologies like GIS mapping, remote sensing, drone-based weed detection, and artificial intelligence can be applied. Understanding regional weed diversity and developing efficient management techniques may be further aided by comparative phytosociological research in other crops and adjacent areas. To support scientific weed management techniques for sustainable cotton production and increased agricultural output, farmer awareness campaigns and extension initiatives should be supported.

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