INJ INTERNATIONAL NEUROUROLOGY JOURNAL

Emerging Trends In The Seeds Market: An Insight Into Hybrid Seeds And Digital Technologies

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Abstract

This study explores the emerging trends in the seeds market, particularly emphasising the emergence of hybrid seeds and the revolutionary potential of digital technology. Analysing the agronomic benefits of hybrid seeds and the effectiveness of digital platforms in the seed industry reveals insightful findings. Hybrid seeds are favoured by farmers for their high yields, disease resistance, and quality, indicating significant agronomic advantages over traditional varieties. However, the correlation among these benefits is complex. There is no direct link between yield and disease resistance but a moderate correlation between disease resistance and quality, underscoring the multifaceted nature of hybrid seed advantages.

Regarding the effectiveness of digital platforms for promoting seed products, company websites, e-commerce platforms, and social media emerge as more effective than mobile apps, e-mail marketing, and online advertisements. This disparity suggests that focusing on specific digital channels could be more beneficial for businesses in the seed industry. At the same time, other platforms might need re-evaluation or different strategies to enhance their impact. This dual analysis provides strategic insights for both agronomic practices and digital marketing in the seed industry.

Key Words: Hybrid Seeds, Digital Technology, Agronomic Benefits, Seed Quality, Traditional Varieties, Digital Platforms, E-commerce Platforms, Agronomic Practices.

Introduction

The global hybrid seeds market is expected to grow at a compound annual growth rate (CAGR) of 9.6% from 2022 to 2031, from an estimated $59,555.2 million in 2020 to $166,189.8 million by 2031, according to Allied Market Research. The market for hybrid seeds has not grown favourably due to the COVID-19 epidemic. The repeated lockdown procedures adversely affected hybrid seed certification, distribution and production. As a result, hybrid seed prices skyrocketed, impacting the market's expansion in 2020. Natural out-breeding crops provide hybrid seeds. Inbred lines are produced from these crops through repeated self-pollination. Established inbred lines are crossed to develop first-generation (F1) hybrid seeds. These seeds enhance the characteristics of resulting plants (F1), as they offer better yield, enhanced colour, significant uniformity and disease resistance. Saving seeds developed from F1 hybrid plants is undesirable, as the generated sources do not reliably create true copies, and thus, new hybrid seeds are purchased for each planting.

Advancing Agriculture with Hybrid Seeds: Balancing Innovation, Sustainability, and Market Dynamics

Hybrid seeds result from controlled cross-pollination between two parent plants, typically resulting in offspring with superior traits. Hybrid seeds can yield crops with higher productivity, better resilience against diseases, and enhanced nutritional quality. There is a need to invest in research to develop hybrid seeds that are resilient to varied climates and less susceptible to infections. Hybrid seeds ensure a higher yield without compromising crop diversity. It is imperative to encourage farmers to continue cultivating traditional and local varieties by providing incentives, technical support, and creating markets for these crops.

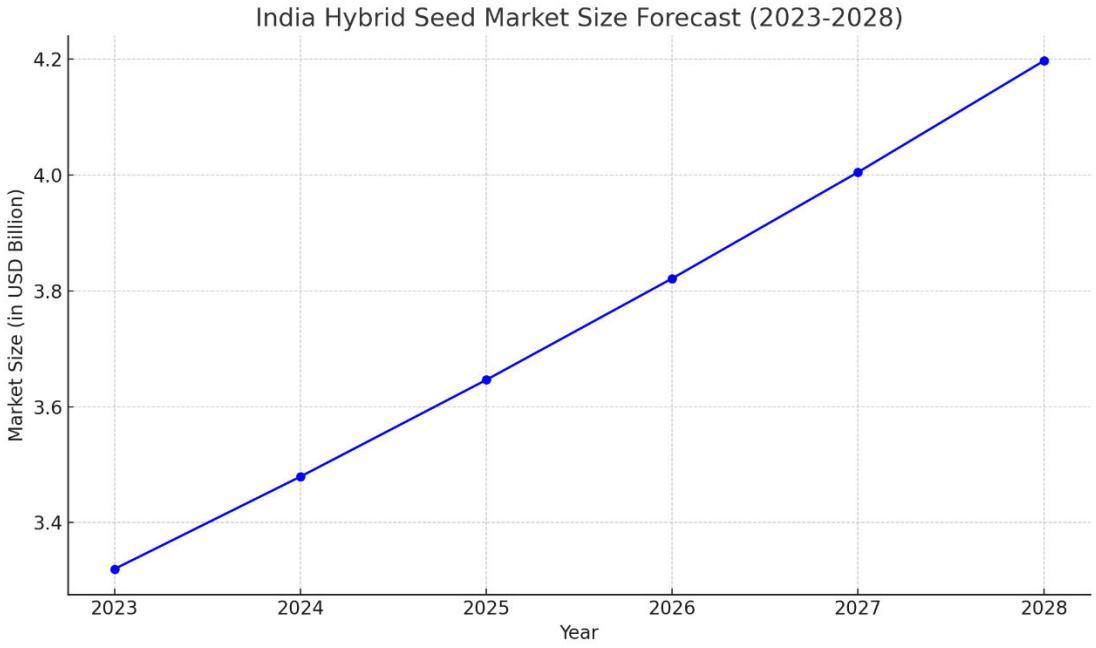
There is a need to facilitate partnerships between the government and private sector to encourage the development of hybrid seeds that align with sustainable agriculture practices and local climate conditions.

Variable climatic conditions and the fact that hybrid seeds cannot be reproduced as the genes in the F1 hybrid get segregated in the offspring hinder the market growth. However, an increase in demand for hybrid seeds in emerging countries is expected to provide lucrative opportunities for market growth. The hybrid seeds market is segmented into crop, duration, seed treatment, farm type and region. The market is categorised based on yield into fields, fruits, and vegetables. By period, it is bifurcated into short-term, medium-term and long-term. Depending on seed treatment, it is segregated into treated and non-treated. Based on farm type, the market is bifurcated into indoor and outdoor. **[1]**

ISSN:2093-4777 | E-ISSN:2093-6931
DOI: 10.5123/inj.2023.4.in115
Vol. 27 Iss. 4 (2023)

A Focus on the Soaring Growth of Fruits and Vegetable Segments in the Hybrid Seeds Market:

According to **newswires**, there is a significant opportunity for market expansion due to the rise in demand for hybrid seeds from developing nations and technology-driven agriculture in industrialised regions. Based on crop, the hybrid seeds market trends show that the fruits and vegetable crops segment generated the most revenue ($40,951.5 million) in 2020 and is projected to grow at a compound annual growth rate (CAGR) of 10.0% to $118,878.4 million by 2031. The market's growth rate for fruits and vegetables is the fastest in volume and value. The fastest-growing category is okra, which is followed by chilli. The okra crop is produced using hybrid seeds that resist the enation leaf curl virus (ELCV) and yellow vein mosaic virus (YVMV). The emergence of hybrids resistant to viruses that cause male sterility and can withstand heat is anticipated to alter significantly the okra crop landscape since more open-pollinated seeds are converted to hybrids. Grown in a wide range of agroclimatic conditions—including rainfed systems—chilli is a widely divided crop according to regional preferences. Therefore, the market for fruits and vegetables is expected to develop due to the considerations mentioned above. [2]



Source: Polaris market research (www.polarismarketresearch.com)

The graph depicts the forecasted growth of India's hybrid seed market size from 2023 to 2028. The market size starts at USD 3.32 billion in 2023 and is projected to grow annually, reaching USD 4.20 billion by 2028, with a compound annual growth rate (CAGR) of 4.80%.

As Per Polaris market research, hybrid seed preparation is an expensive and complicated process, which is projected to limit industry expansion. They are also incapable of surviving in shifting environmental circumstances and reproducing once planted in the field. Furthermore, lack of customer awareness and biotic stress-tolerant hybrids are two essential obstacles to the hybrid seeds market growth. [3]

Salient issues to understand advantages, Challenges, and Strategic Developments in the Hybrid Seed Market

Farmers' preference for hybrid seeds and the problems with hybrid seeds.

Hybrid seed growth is quicker and simpler. Plants can be improved with hybrid seeds to have higher yields, more uniformity, better colour, and resistance to diseases. They are resistant to disease, have a higher yield, have bigger fruits, and can stand stress better. They outlive the other seeds in terms of longevity.

Every year, hybrid seed problems must be solved because the traits are passed on to the following generation and are not retained. Furthermore, producing hybrid seeds comes at a significant expense.

Potential challenges to the hybrid seeds market.

Challenges like unorganised new entrants with a low profit-to-cost ratio, the commercialisation of fake hybrid seeds and counterfeit products, and Initial breeding of hybrid seeds are some of the challenges faced by the hybrid seed market.

Companies in the hybrid seed market undertake key development strategies.

Strategies such as large-scale awareness, new product launches, investments into expansion and development of hybrid seeds and research initiatives are the key strategies prominent players use to achieve differential positioning in the global market. **[4]**

Factors influencing market growth

Sphere Insights reports state that the global market for hybrid seeds is primarily driven by the increasing use of hybrid seeds with various advanced features, such as coating and pelleting, biological and mechanical innovations related to farms, the introduction of improved hybrid seed varieties, the decrease in arable land, and the diversification of diets.

The total growth of the market may be slowed down by the shift in climatic conditions and the straightforward reality that hybrid seeds are unreproducible since two different gene types separate in the progeny of F1 hybrids, producing highly distinct offspring. It is anticipated that industrialised countries' technology-based agriculture and developing countries' varied need for hybrid crops will offer robust prospects for worldwide market expansion. **[5]**

Impact Analysis of COVID-19

According to OECD.org, in the first quarter of 2020, the COVID-19 epidemic significantly impacted hybrid seed certification, production, distribution, and price. The COVID-19 epidemic has catalysed the strengthening of food systems and agriculture industries in less prosperous nations. The worldwide commerce of seeds faced challenges due to a shortage of labour for the transport, production, and documentation processes, as well as a decrease in the quantity of plants and seeds available for purchase. The outcome was a drop in the global market. **[6]**

Regional Insights

The Asia Pacific region gained the largest share of the hybrid seeds market in 2021 and will likely maintain that share over the forthcoming period. India holds the largest share of the hybrid seed market in the Asia Pacific. The largest share is due to the increasing demand for fruit and vegetable crops. **[7]** Due to the expanding area used for indoor farming and the need for organic fruits and vegetables and high-valued fruits, vegetables, and flowers that can quickly and efficiently be grown indoors, indoor farms have a high market share. [8]

Concerning the most recent trends and propelling factors, the report provides insightful information on the current status of the worldwide hybrid seeds market. Potential growth drivers, the current market share distribution, and the adoption rate of various types, technologies, applications, and regions through 2030 are all included in the Hybrid Seeds Market Report. **[9]**

Shift towards hybrid seeds.

Over the past few decades, there's been an increased adoption of hybrid seeds, especially in crops like cotton, maise, and vegetables. These seeds offer better yields, pest resistance, and other desired traits. The shift towards hybrid seeds over the past decades is a prominent trend in modern agriculture, as hybrid seeds offer several advantages over traditional or open-pollinated seeds. The following inputs showcase a demonstration of this shift:

Enhanced Productivity and Yield: Farmers can increase yield and productivity by specifically cross-breeding hybrid seeds to boost their desired characteristics. They provide increased vigour, insect resistance, and environmental flexibility. Hybrid seeds thus play a significant role in global food security and sustainable agricultural expansion. The resulting plants are usually more productive when hybrid seeds are used instead of standard ones because of the "heterosis" or hybrid vigour concept. **[10]**

Disease and pest resistance: By carefully choosing parents, resistance characteristics are passed down to the offspring, which lowers the demand for chemical pesticides. Reducing chemical removal protects the environment and guarantees safer crops for human consumption. Additionally, crops cultivated from hybrid seeds resistant to pests and diseases typically offer larger yields and better quality, which benefits farmers financially.

Hybrid seeds can decrease the requirement for chemical interventions by engineering to be more resistant to specific diseases and pests. [11] Major insect pests of field and vegetable crops and the extent of losses caused by them are as follows:

Major pests and percentage of crop loss

Crop	Major pests		% Crop loss	Reference
	Common name	Scientific name		
Cabbage	Diamond back moth	Plutella xylostella	52	Chellaiah & Sreenivasan, 1986
	Cabbage Webber	Crocidolomia binotalis		
	Cabbage borer	Hellula undalis		
Cauliflower	Diamond back moth	Plutella xylostella	52	Chellaiah & Sreenivasan, 1986
Okra	Shoot and fruit borer	Earias vittella		
	Fruit borer	Helicoverpa armigera		
Tomato	Fruit borer	Helicoverpa armigera	46	Singh, 1991
Brinjal	Shoot and Fruit borer	Leucinodes orbonalis	92	Mall, 1992
	Stem borer	Euzophera perticella		
Chilli	Fruit borer	Helicoverpa armigera		
	Fruit borer	Spodoptera litura		
Melons	Melon fruit fly	Dacus cucurbitae	80	Panwar-1995
	Pumpkin beetle	Raphidopalpa foveicollis		

Source: Chellaiah & Sreenivasan, 1986; Singh, 1991; Mall, 1992; Panwar-1995.

iii) Improved product characteristics: Improved product characteristics of hybrid seeds refer to the enhanced traits of crops produced from these seeds. Such improvements can include better taste, increased nutritional content, longer shelf life, and more attractive appearance. These enhancements result from combining the best qualities of two parent plants, ensuring superior produce compared to traditional varieties. Hybrids can be tailored for better taste, colour, or shelf life, factors that are vital for the food industry.

iv) Drought and stress tolerance: The term "drought and stress tolerance" in hybrid seed refers to the improved capacity of hybrid plants to endure low water availability and unfavourable weather. These hybrids are created by fusing genes from parent plants with desired resilience-promoting characteristics. Because of this, hybrid crops may continue to grow and produce even in less-than-ideal circumstances, guaranteeing food security and financial success for farmers in challenging climates. Hybrids that can handle the impending risks of water scarcity and climate change are highly sought after. [12]

v) Economic Incentives for Seed Companies: Because hybrids are proprietary, there are advantages for seed companies to produce hybrid seeds, including higher profit margins. Farmers frequently repurchase hybrid seeds yearly because preserved seeds may not consistently reproduce the intended features. This guarantees businesses a steady flow of income, encouraging research expenditures and accelerating the expansion of the seed sector. Farmers must buy fresh hybrid seeds for each planting season since they do not resow true to type, which impacts the economy and raises issues related to farmer dependence.

vi) Enhanced Uniformity: Enhanced uniformity of hybrid seeds means that the resulting plants exhibit consistent growth, appearance, and yield. Such predictability benefits farmers by ensuring even crop maturity and simplifying cultivation practices. For crops that require mechanical harvesting, uniformity is critical. Hybrid seeds offer this uniformity, ensuring plants mature at the same time.

vii) Private Sector Participation: Earlier, the seed sector in India was predominantly public-driven. But over the years, private players have played a significant role, leading to increased competition, research, and development. [13]

viii) Organic Farming and Traditional Seeds: Organic farming uses traditional seeds to promote biodiversity and natural processes. Without any genetic manipulation by humans, this has developed over many generations. They promote genetic diversity by offering a variety of flavours and adaptability to local conditions while avoiding industrial pesticides and fertilisers essential to conventional farming. There is an increased interest in traditional and indigenous seed varieties due to the growth of organic farming and consumer awareness of environmental and health issues. [14]

ix) Government Initiatives: To increase agricultural output, governments frequently promote hybrid seeds, aiming to improve food security, farmer incomes, and sustainable agricultural practices. Initiatives include support for research, farmer education programmes, and subsidies for purchasing hybrid seeds. The "National Seeds Mission" is just one of the many programmes the government has started to support the seed business.

These programmes are meant to encourage the use of high-yielding cultivars and increase seed replacement rates. [15]

x) Increased Investment in R&D: Increased research and development spending on hybrid seeds is to create better varieties with attributes like increased yields, disease resistance, and climate adaptation. Through providing funds for research, governments and businesses hope to solve issues related to food security, improve crop profitability, and optimise farming techniques—all of which will propel agricultural innovation and sustainable growth to create seeds that are high-yielding, pest-resistant, and appropriate for the changing climate, both the public and private sectors have been investing in research and development. [16]

xi) Quality Assurance and Certification: Hybrid seeds that meet quality assurance and certification requirements are guaranteed to meet genetic uniformity, viability, and purity standards. These characteristics are verified by certification agencies, which ensures farmers get seeds that function as expected, increasing crop accuracy and trust in seed companies. More stringent quality assurance and certification procedures are being implemented to guarantee the calibre of seeds available for purchase. [17]

xii) Digital and Technological Integration: The market for hybrid seeds benefits from digital and technology integration, which uses technologies like precision agriculture and data analytics to track performance, anticipate market trends, and optimise seed development—all of which increase productivity and farmer profitability. Agri-tech businesses, digital platforms, and seed e-commerce make high-quality seeds more accessible to farmers. For seed traceability, blockchain-based technologies are also being investigated. [18]

xiii) Biofortification: Breeding for biofortification increases the nutritious content of crops. It provides a sustainable solution for micronutrient deficiencies, improving overall population health by supplying vital vitamins and minerals in staple foods to fight the malnutrition problems common in some parts of India; there is growing interest in seeds that yield nutritionally enhanced crops. [19]

Review Of Literature

Since the '70s, hybrid seed production has dramatically increased, driven by the higher value of hybrids in the marketplace. Seed companies and growers have thus far realised a greater return. Unfortunately, the motivation behind hybrid research is more about increased profits than sustainable production. The worldwide demand for hybrid seed has fostered the abandonment of seed production of native varieties. The number of seed-saving farmers has diminished. The apparent result is genetic vulnerability. By offering both OP and hybrid varieties, seed companies may reduce their bottom line but contribute to maintaining genetic diversity. If a small quantity of some of the old varieties were maintained by each seed company for homeowners, organic farmers and some commercial-scale growers, and the unique characteristics of each OP variety were identified, genetic diversity could be more easily maintained for crises.

Market Trends and Promising Technologies

i) Global Seed Market Growth and the Role of Private Sector Innovation

In 2023, Malavika Dadlani highlighted the robust growth in the global seed market, which is anticipated to reach USD 86.8 billion by 2026, driven by a 6.6% compound annual growth rate (CAGR). The focus is not just on crop improvement and seed quality but also on addressing challenges posed by climate change and enhancing nutritional value. The seed market is evolving with advanced hybrid techniques and precision breeding, adapting to the demands for high-quality seeds that perform well in challenging environments. Cutting-edge technologies like digital phenotyping and 3D imaging are at the forefront of revolutionising seed quality evaluations. Moreover, innovative techniques in seed production were developed and marketed, signifying a shift towards more advanced agricultural practices. [20]

Ira Matuschke and Matin Qaimin's 2008 study underscores the significant role of private firms in seed development and distribution, leading to higher innovation rates. Their research confirms that private sector involvement remains impactful, even in subsistence crops like millet. This involvement is key to maintaining low seed prices and fostering competition in crop improvement research and development, potentially yielding superior technological products. Policymakers are encouraged to promote private sector activities by creating a supportive institutional framework. This includes improving information flows and market infrastructure to facilitate the diffusion of innovative crop technologies. In India, while input dealers and fellow farmers are the primary information sources for farmers, the public extension service, though currently less significant, could be enhanced to provide more objective and timely information. This strategic support can significantly aid in the widespread adoption of advanced agricultural technologies and practices. [21]

According to **Tom Crompton and Vandana Shiva**, 2015 This report elucidated the various reasons to anticipate that a small number of multinational corporations will control most of the seed industry. Larger seed companies are primarily responsible for producing hybrid seed, and as a result of the following factors, its use is

expected to rise: - the public sector's decline; - public sector initiatives to boost farmers' acceptance of hybrid seed and reduce their use of farmer-saved seed; and - private sector marketing and promotion tactics. Smaller businesses will find it harder to compete because: - the market is irregular, making it harder for them to weather swings in favour of competitors' seeds, and - plant variety protection will stifle demand for both open-pollinated and hybrid seeds in second and subsequent generations. [22]

ii) The Evolving Landscape of the Vegetable Seed Industry in India and the Role of Public-Private Partnerships

According to **Mohan et al. 2021**, the vegetable seed industry holds significant potential, especially in nations like India, where a vast majority engage in agriculture. Ensuring timely access to quality seeds at reasonable costs is vital. Strict enforcement of seed regulations is necessary to guarantee quality and safeguard farmers from counterfeit sources. Policies should align with the contemporary needs of farmers and the nation. The public sector needs bolstering in research and development to offer competitively priced, quality seeds, rivalling private enterprises. Collaborations between public and private entities can elevate vegetable seed production quality. While large seed corporations with robust R&D might not prioritise partnerships, emerging seed companies can benefit. Like other countries, India has heavily invested in public agricultural research, focusing on technology generation and dissemination. The landscape is evolving, with rising private sector influence due to technological advancements and more substantial intellectual property rights. The surge in private investment in agricultural research can significantly boost economic growth in developing nations. [23]

In their 2013 study, Aniruddha Maity and S. K. Chakrabarty explored the impact of environmental factors on hybrid seed quality, particularly in mustard seeds. They found that seed germination and vigour rates vary with sowing seasons, influenced by temperature and humidity changes during vegetative, reproductive, and harvest stages. The physiological quality of seeds at harvest affects their performance in accelerated ageing and germination tests. As mustard seeds near maturity, they accumulate soluble sugars and various Late Embryogenesis Abundance (LEA) proteins. The study also revealed that environmental conditions during development and maturation significantly affect seed quality, a genetically inherited trait. Unfavourable weather conditions during development can hinder quality, increase ageing susceptibility, and affect responses in accelerated ageing tests. Indian mustard, in particular, thrives at higher temperatures during vegetative growth and lower temperatures during the reproductive phase. [24]

According to **KB Saxena and N Nadarajan,** in 2010, pigeon pea productivity had stagnated for years, but recent advancements signal a positive shift towards hybridisation. Early results highlight the potential of leveraging hybrid vigour in pigeon pea farming. In 2009, on-farm trials in Maharashtra's Amravati and Yavatmal districts showed impressive yields, with farmers producing over 4 tons per hectare. Another farmer in Andhra Pradesh's Medak district reaped a hefty profit from his hybrid crop. These findings indicate that hybrid technology can overcome pigeonpea's yield stagnation. The advent of consistent CMS systems accelerates pigeonpea hybrid research. ICRISAT and ICAR are pioneering these advancements, suggesting that commercial pigeonpea hybrids in India will soon become mainstream. [25]

Effective Digital Technologies In The Seeds Market

Concerns over the world's food supply security have made next-generation industrial farms and intensive agricultural practices more necessary. Digital technologies made possible by the industry project are at the forefront of this new era of agriculture and are proposing a wide range of innovative solutions. [26]

i) Integrating Disruptive Technology in Agriculture: Perspectives on Digitization and the Future of Rural Business

Researchers and the scientific community actively integrate disruptive agricultural technologies to preserve process inputs, minimise costs, and enhance crop yields. This ongoing effort is a significant addition to the research on agricultural digitisation. As Rabiya **Abbasi et al. (2022)** suggest, there's a need to consider more research databases and factors for future studies to present a comprehensive perspective of the agriculture industry's digitisation. This approach will deepen our understanding of the technological transformation in agriculture. [27] Similarly, **Bruce Small's 2017** study explained the future of digital technologies and their potential impact on rural businesses and lifestyles. Embracing Gibson's idea that the future is already here, albeit unevenly distributed, Small examines cutting-edge technologies nearing mainstream adoption. He discusses critical drivers shaping technological evolution, such as convergence, miniaturisation, cost reduction, and the Law of Accelerating Returns. Minor emphasises the importance of foundational digital technologies, especially in rural contexts. These advancements redefine agricultural efficiency, workforce needs, value chains, business models, and rural living. With numerous emerging technologies in the agricultural sector, small stresses the need

for rural communities and businesses to embrace adaptability, harness the opportunities of the digital shift and prepare for changing consumer demands. [28]

According to **Alexandra TCACENCO and Liudmila TODOROVA**, 2019, Drones typically withstand the significant obstacles of the twenty-first century. Future developments in the drone industry will enable agriculture to become more data-driven, which will cause a change in farming's efficiency and output. The aircraft are comparatively inexpensive, simple to operate, highly mobile, and excellent for crop monitoring. Frequent analysis can turn agriculture into a high-tech sector by reducing inefficiencies and improving management. This fact implies that rather than concentrating on device specifications, the quality and capabilities of data collecting must come first. Thus, developing institutions require more complex sensors and cameras. A further trend may be the creation of hybrid aerial-ground drones capable of collecting data but performing a share of tasks. [29]

Digitisation is the reality for the agriculture industry today. As the large input companies are to keep up with new entrants and meet the demands of farmers, regulators, and consumers, they must build new cross-functional capabilities in data, analytics, and digital technology. They need to maintain separate digital units or centres of excellence, further streaming their digital efforts. The company must think digitally to maximise its innovation potential **Kurth et al., 2020**. [30]

ii) Balancing Environmental Impact and Technological Transformation in Agriculture

In their 2023 study, **Jennifer Clapp and Sarah-Louise Ruder** investigated the environmental impacts of precision farming technologies. Proponents of these technologies praised their ability to reduce pollution, combat climate change, and enhance resource efficiency for farmers. However, critics raise concerns about potential environmental hazards and the risk of increasing corporate dominance, potentially jeopardising farmers' independence. Some suggest adopting systems based on agroecological principles for sustainable agriculture. These technologies also significantly shape governance and policy, reflecting complex interactions between societal influences and technological access. While major agricultural companies aim to control these technologies, civil society organisations and startups are exploring ways to ensure sustainability and equity in precision agriculture. [31] **Ciarli et al. (2021)** further discuss how digital technologies revolutionise farming. They note that simply training farmers to use new equipment won't prevent the replacement of farmers or farm labourers. Instead, farmers are likely to assume higher-level decision-making roles, requiring skills in accounting and software expertise for equipment and software updates. Automation also means farmers can operate with fewer workers, replacing human labour with hardware and software. A significant challenge for farmers will be identifying instances where software makes suboptimal recommendations or decisions. [32]

Data and technology interventions, according to Srikanta Bhaskara and Kamaljit S. Bawa (2021), can aid in the achievement of sustainable development goals in any field. As we've shown, information systems targeted at the seed sector can boost output and profits while also helping the environment by requiring fewer pesticide and fertiliser inputs. These systems are reasonably priced. The platform's unit costs could be further decreased by expanding to include additional farmers. Benefits might rise as more information is included. It could be argued that income growth as an outcome of these practices has been negligible. It is important to remember, nevertheless, that creating, testing, and proving the cost-effectiveness of an information system was one of the main objectives. Income may be further increased by combining information with interventions like higher digital literacy, crop and soil management, increased crop variety, improved disease control, improved market access, and effective market linkages.[33]

According to a 2020 study by Upendra et al. on the assessment of technology use in the seed industry, there are a number of techniques available to improve crop output and quality. Unlike other industrialised nations, the non-maintenance of resources critical to the functioning of production systems makes it difficult for India to achieve the expected growth. Several factors affect how well quality farming is used. The application of technology in this field has led to innovations such as agricultural yield analytics and digital precision agriculture. There is a gap between farmers and technology in India, where a sizable portion of the population works in agriculture. Governments have included several techniques in agriculture to assist farmers in utilising technology. Despite this, there is still room for user-friendly, comprehended agro-advisory systems to support farmers in choosing which crops to plant. Additionally, these technological innovations ought to assist farmers in obtaining the maximum output at lower costs at various crop growth stages. [34]

Role of Mobile Phone Technology in Improving Hybrid Seed Market

In their 2014 study, **Surabhi Mittal and Gaurav Tripathi** explored the transformative potential of mobile phones in the seeds market. Mobile phones have shown considerable promise in boosting the market with their mobility, tailored content delivery, and convenience. As mobile adoption rises among farmers, the scope for its impact broadens. However, maximising this potential necessitates overcoming barriers that hinder farmers from utilising mobile-provided information. Crucially, service providers must tap into mobile benefits like portability and two-way communication for cost-effective, customised solutions. While many farmers primarily view mobile phones as communication devices, infrastructural deficiencies and resource challenges can stifle their broader benefits. To fully harness information, farmers must be willing to adopt new techniques. Enhanced extension services can supplement mobile-driven information, expediting the uptake of innovative approaches. **[35]**

"The Impact of Mobile Phone Technology on Agricultural Extension Services Delivery: Evidence from India," a research paper by **Shaheen Akter and Xiaolan Fu, 2016**, looks at how mobile phone technology affects the execution of agricultural extension services in India. The results show that this intervention significantly improved the quantity, quality, and speed of service delivery. The study highlights the advantages in terms of farmers' aspirations to adopt new technology, improved access to credit, and higher knowledge and awareness of new agricultural practices. Additionally, it highlights how the system helped farmers from underprivileged and low-education backgrounds, indicating that technology when applied properly and supported by skilled village youths, can be a powerful force for sustainable growth. **[36]**

Smart Farming

Amidst the growing excitement for a "smart" agricultural revolution, concerns arise regarding managing digital innovations like data-collecting tractors and their algorithms. **Kelly Bronson** (2018) emphasises considering who benefits from these technologies. Evidence suggests that big data and machine intelligence could strengthen power dynamics, favouring significant agribusinesses. An example is Monsanto's Fieldscripts, a platform using proprietary algorithms to recommend specific seeds for field conditions. The platform lacks transparency in its algorithm and its profit-driven motives. By using FieldScripts, farmers essentially become dependent on Monsanto, which profits from integrating machinery, data, seeds, and chemicals. **[37]** Smart farming has the potential to yield enormous social and environmental advantages in addition to increased efficiency and food production, as noted by **David Christian Rose and Jason Chilvers (2018).** However, they also advised on the potential ethical, social, and ecological effects. They contend that whereas frameworks for responsible innovation are essential for the agritech revolution, they fall short in addressing the broader range of technologies. Responsible innovation needs a framework that can effectively shape the social trajectories of creation to be successful. We may assess these frameworks' impact on innovation designs by testing them. Crucially, the people most impacted by these technologies should guide the questioning process, challenging whether productivity gains should overshadow other concerns and prompting shifts in innovation towards sustainable agriculture. **[38]**

Smart farming can offer a coordinated way out of embedded technologies and practices marked by extreme polarisation and market segmentation (**Waltera et al., 2017**). Diversifying technology, crop and livestock production systems, and networks, including all players in the agri-food industry, provides a route towards sustainable agriculture. A single policy strategy cannot realise this goal, which encourages and enables the responsible use of ICT technology. Instead, the goal is to pinpoint the prevailing mechanisms that restrict or jeopardise a sustainable use of technology and then determine which courses of action, in both developed and developing nations alike, are most appropriate and could lead to improved finance availability in certain situations and targeted investment support in other cases. Furthermore, expenditures in education and training, or the deployment of collectively operated uncrewed aerial aircraft to monitor entire villages' worth of fields, can help ensure that these technologies are used effectively. Nonetheless, the policy environment should always offer a precise legal framework that permits efficient ownership and user rights. **[39]**

Statement Of The Problem

It's critical to understand how hybrid seeds and digital marketing techniques affect the seed market in the quickly changing seed industry. Although hybrid seeds have the potential to provide agronomic benefits, including increased yield and disease resistance, a number of factors, including farmer preferences and environmental conditions, affect their acceptance and effectiveness. Furthermore, with the development of digital technology, there is still more research to be done on the effectiveness of different digital platforms for seed product promotion. These two areas are the focus of this study: the advantages and difficulties of hybrid seeds from an agronomic viewpoint, as well as the effectiveness of various digital marketing platforms for the seed sector. In order to provide insights that may direct future agricultural practices and seed industry marketing

tactics, the research aims to resolve the complexity surrounding the adoption of hybrid seeds and the strategic use of digital platforms.

Research Questions

1) How do the yields of hybrid seeds compare to traditional varieties in quantity, quality, and consistency across different environmental conditions?
2) What is the comparative resistance of hybrid seeds against pests, diseases, and extreme weather events relative to traditional seed varieties?
3) What factors influence farmers' decisions to adopt hybrid seeds over traditional varieties? Are these factors primarily economic, agronomic, or influenced by external pressures such as market demands or policy changes?
4) Which digital platforms are most frequently used by farmers for seed selection, purchase, and cultivation guidance? How effective are these platforms in providing accurate and timely information?
5) What challenges or obstacles do farmers face in integrating digital technologies into their seed selection and farming practices? Are these barriers technological, educational, economic, or cultural?

Objectives

To evaluate the agronomic benefits of hybrid seeds and understand farmers' adoption preferences over traditional varieties.
To assess which digital platforms are predominantly used by customers effectively.

Hypothesis Of The Study

Hypothesis 1: (H1) The adoption of hybrid seeds is positively associated with higher average yields, better disease resistance, and improved quality of produce.
(H0): There is no significant association between the adoption of hybrid and average yields, disease resistance or quality of produce.
Hypothesis 2: (H1) Among the various digital platforms, company websites, e-commerce platforms, and social media are significantly more effective for promoting seed products than other mobile apps, e-mail marketing, online workshops and online advertisements.
(H0): There is no significant difference in effectiveness among the different digital platforms for promoting seed products.

Research Methodology

Descriptive and explanatory Research designs were employed to assess the agronomic advantages of hybrid seeds and comprehend farmers' inclinations towards them instead of traditional varieties. This approach involved surveying a diverse group of farmers at a single point in time to gain insights into their seed preferences, reasons for choice, and perceived benefits. Additionally, an **Exploratory Research Design** was utilised to discern which digital platforms are predominantly favoured by customers for seed-related purposes. This entails monitoring user activity and engagement on various digital platforms, allowing for an objective understanding of platform effectiveness and popularity among the user base. Together, these research designs provide a comprehensive view of current trends and preferences in the seed market.

This study sought to evaluate the agronomic advantages of hybrid seeds over traditional varieties, comprehend farmers' preferences in seed adoption, and determine the prevalent digital platforms employed effectively by customers. The research used stratified and cluster sampling methods to ensure a comprehensive and representative data collection. **Stratified sampling** ensures that specific sub-groups, possibly based on farm size, crop type, or geographical region, are adequately represented. Meanwhile, cluster sampling will allow the categorisation of larger groups, perhaps entire farming communities or areas, into randomly selected clusters, ensuring that the research is efficient and captures the diversity inherent in the broader farming population.

A questionnaire was used to gather primary data for the study. Preliminary data is first-hand information that has been collected directly from respondents, and the following sources were used to gather secondary data for the creation of the research framework and literature review:

- Google and Google Scholar
- Books and research articles from journals.
- Organisational websites
- Government Records and Reports

- Compendium and Booklets

A study comparing hybrid seeds to conventional seed kinds was conducted to investigate hybrid seeds' agronomic benefits. The study also aimed to determine how much farmers tended to favour one variety of seed over another. Furthermore, the study sought to identify the internet channels consumers favoured the most for their farming endeavours—a **sample size of 49** participants was used to obtain thorough insights for this research.

To comprehend the evolving dynamics of the seeds market, a study was initiated to evaluate three core areas: the agronomic benefits of hybrid seeds, the preferences of farmers in adopting these seeds as opposed to traditional varieties, and the prevalent use of digital platforms by farmers for seed-related information and purchases. For this purpose, **dealers' and marketers'** primary sampling units ensure direct insights into their experiences, practices, and preferences regarding hybrid seeds and digital technology adoption.

Scope of the study: This study focuses on the multifaceted domain of the seeds market by focusing on three primary dimensions. First, it seeks to evaluate the agronomic advantages of hybrid seeds, specifically their yield, resilience, and overall performance, compared to traditional seed varieties. Second, the research will explore the factors and motivations behind farmers' choices, aiming to decipher why some might prefer hybrid seeds while others remain loyal to traditional varieties. Lastly, in the context of the digital age, the study will identify which digital platforms are most popular and influential among users for seed selection, cultivation guidance, and other agricultural endeavours. Through this integrated approach, the research aspires to provide a comprehensive insight into the contemporary dynamics of the seeds market.

Data Analysis And Interpretation

FREQUENCY TABLE

1. Classification of respondents according to gender

Table 1: Gender-wise classification of the respondents

Particulars	Classification	Respondents	Percentage
Gender	Male	45	91.84 %
	Female	4	8.16 %

The total number of respondents taken is 49. The survey reveals a significant gender disparity with 91.84% male respondents, indicating that males predominantly evaluate hybrid seeds, which may offer higher yields and disease resistance compared to traditional varieties. This suggests a need to understand and address the barriers to female farmers' adoption preferences.

2. Classification of respondents according to age.

Table 2: Age-wise Classification of respondents

Particulars	Classification	Respondents	Percentage
Age	[1] 18-24 years	1	2.04 %
	[2] 25-34 years	9	18.37 %
	[3] 35-44 years	19	38.78 %
	[4] 45-54 years	14	28.57 %
	[5] 55-64 years	4	8.16 %
	[6] 65 Above	2	4.08 %

The total number of respondents taken is 49. The agronomic benefits of hybrid seeds drive adoption across age groups, with 38.78% of adopters aged 35-44 years indicating a preference for innovation in mid-career farmers. Older generations show less inclination, while the youngest (18-24 years) barely engage at 2.04%, suggesting a need for targeted awareness and education.

3. The average yield from hybrid seeds compared to traditional varieties.

Table 3: Average Yield from hybrid seeds compared to traditional varieties

Particulars	Classification	Respondents	Percentage
Average yield	[1] Significantly lower	0	0 %

	[2] Slightly lower	0	0 %
	[3] About the same	4	8.16 %
	[4] Slightly higher	18	36.73 %
	[5] Significantly higher	27	55.10 %

The total number of respondents taken is 49. The survey highlights a clear trend: hybrid seeds outperform traditional varieties, with 55.10% reporting significantly higher yields and 36.73% observing slight increases. Only 8.16% see no difference. This data underscores the effectiveness of hybrids in enhancing productivity, a potential pivot point for agricultural practices.

4. Improvement in disease resistance with hybrid seeds.

Table 4: Disease resistance improvement

Particulars	Classification	Respondents	Percentage
Disease Resistance	[1] No resistance	2	**4.08 %**
	[2] Less resistance	1	**2.04 %**
	[3] No difference	10	**20.41 %**
	[4] Slightly improved resistance	20	**40.82 %**
	[5] Significantly improved resistance	16	**32.65 %**

The total number of respondents taken is 49. A survey on hybrid seeds indicates a positive trend in disease resistance: 32.65% report significantly improved resistance, 40.82% note a slight improvement, whereas 20.41% observe no difference. Only a small fraction reports no or less resistance, at 4.08% and 2.04%, respectively, suggesting hybrids generally enhance disease resilience.

5. The rate of quality of produce from hybrid seeds.

Table 5: Quality of produce rated

Particulars	Classification	Respondents	Percentage
Rate of quality produce	[1] Poor	0	**0 %**
	[2] Fair	4	**8.16 %**
	[3] Good	6	**12.24 %**
	[4] Very good	28	**57.14 %**
	[5] Excellent	11	**22.45 %**

The total number of respondents taken is 49. A survey assessing produce quality from hybrid seeds yields promising results—an overwhelming 57.14% rate the quality as very good, while 22.45% even deem it excellent. Good quality is reported by 12.24% of respondents. A smaller segment, 8.16%, considers the quality fair. Remarkably, none find the quality poor. These findings underscore the efficacy of hybrid seeds in producing high-quality yield, reflecting a predominantly positive reception among farmers.

6. The importance of the following factors to adopt hybrid seeds.

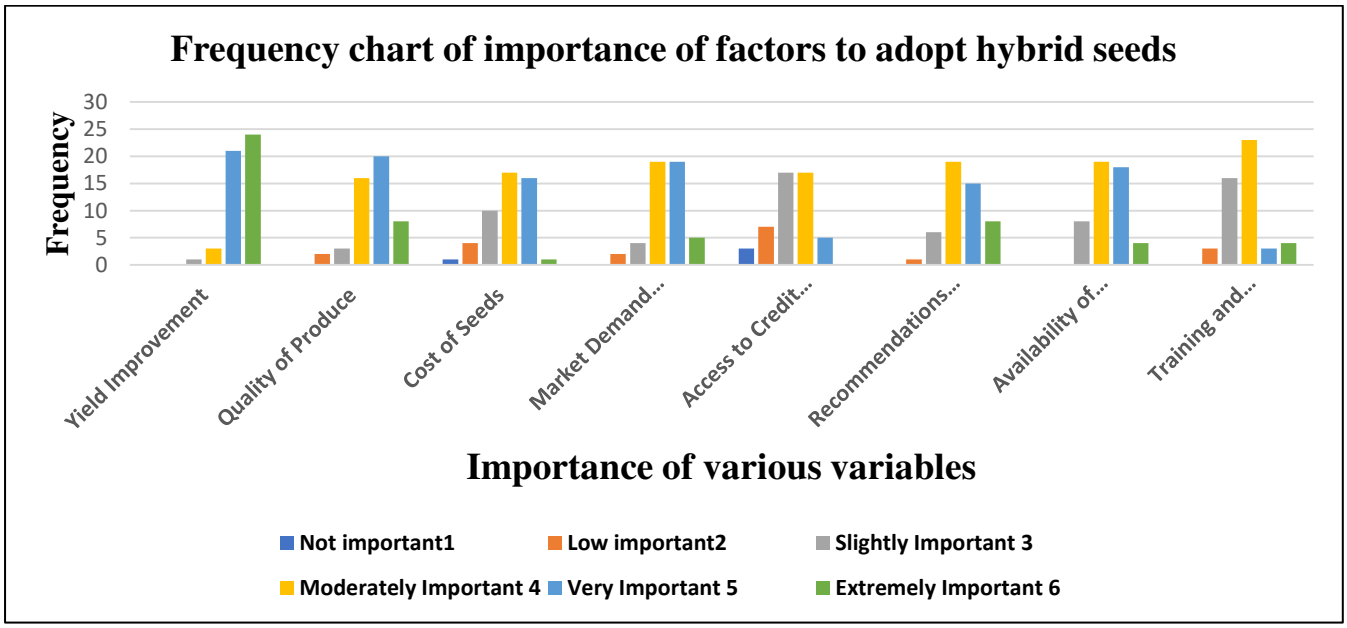
[S1] Not important [S2] Low important [S3] Slightly important [S4] Moderately important
[S5] Very important [S6] Extremely important

Table 6: Importance of factors in intent to adopt hybrid seeds

Variables	**Respondents**					
Scale	S1	S2	S3	S4	S5	S6
Yield Improvement	0	0	1	3	21	24
Percentage	0 %	0 %	2.04 %	6.12 %	42.9 %	48.0 %
Quality of Produce	0	2	3	16	20	8
Percentage	0 %	4.08 %	6.12	32.65 %	40.82 %	16.33 %
Cost of Seeds	1	4	10	17	16	1
Percentage	2.04 %	8.16 %	20.41 %	34.69 %	32.65 %	2.04 %
Market Demand for Hybrid Produce	0	2	4	19	19	5
Percentage	0%	4.08 %	8.16 %	38.78 %	38.78 %	10.20 %
Access to Credit for Seed Purchase	3	7	17	17	5	0
Percentage	6.12 %	14.29 %	34.69 %	34.69 %	10.20 %	0 %
Recommendations from Other Farmers	0	1	6	19	15	8

DOI: 10.5123/inj.2023.4.in115
ISSN:2093-4777 | E-ISSN:2093-6931
Vol. 27 Iss. 4 (2023)

Percentage	0 %	2.04 %	12.24%	38.78 %	30.61 %	16.33 %
Availability of Hybrid Varieties	0	0	8	19	18	4
Percentage	0 %	0 %	16.33 %	38.78 %	36.73 %	8.16 %
Training and Extension Services	0	3	16	23	3	4
Percentage	0 %	6.12 %	32.65 %	46.94 %	6.12 %	8.16 %



As per the table and graph, the following results were found:

Yield Improvement: The survey underscores the significance of yield improvement with hybrid seeds, as an overwhelming 91.84% rate it as very or extremely important. Moderate importance is noted by 6.12%, while only 2.04% see it as slightly important. The absence of votes for 'not important' or 'low important' emphasises the critical value placed on yield enhancement.

Quality of Produce: The survey reveals the significance of produce quality: a substantial 40.82% rate it as very important and 16.33% as extremely important. Moderately important is the view of 32.65%, while a smaller cohort considers it slightly important (6.12%). Only 4.08% deem it of low importance, with none finding it unimportant, highlighting quality's paramount role in agriculture.

Cost of Seeds: The survey reveals diverse views on seed cost importance: 32.65% find it very important, while 34.69% rate it as moderately important. Slightly important comes in at 20.41%. Fewer respondents consider it low in importance (8.16%) or not important (2.04%), with a marginal 2.04% viewing it as extremely important, indicating cost is a significant, but not paramount, factor.

Market Demand for Hybrid Produce: The survey reveals that market demand for hybrid produce is considered important; a significant 38.78% view it as very important, with an equal percentage rating it moderately important. Notably, 10.20% feel it's extremely important. Only a small minority see it as slightly or low important, at 8.16% and 4.08%, respectively, with none deeming it unimportant.

Access to Credit for Seed Purchase: Survey data reveals varied perceptions on the importance of credit for seed purchases: 34.69% find it slightly important and another 34.69% moderately important. A significant minority, 14.29%, view it as low in importance, while 10.20% consider it very important. Interestingly, none categorise it as extremely important, and 6.12% deem it not important.

Recommendations from Other Farmers: The survey reveals that farmers highly value peer recommendations, with 30.61% rating them as very important and 16.33% as extremely important. Moderate importance is assigned by 38.78%, while 12.24% view them as slightly important. Only a minimal 2.04% consider them low importance, with none deeming them unimportant.

Availability of Hybrid Varieties: The survey reveals the critical value of hybrid varieties in agriculture, with 36.73% rating their importance as very high and 8.16% as extremely important. A moderate importance is acknowledged by 38.78% of respondents, while 16.33% see it as slightly important. Interestingly, no one deems it unimportant, highlighting the widespread recognition of the benefits of hybrid seeds.

Training and Extension Services: The survey highlights the significance of Training and Extension Services in agriculture, with a majority finding them at least moderately important (46.94%). 'Slightly important' accounts for 32.65%, while 'very important' and 'extremely important' are deemed so by 6.12% and 8.16% respectively. Notably, 'low importance' and 'not important' are minimal or non-existent.

7. The most affecting drawback of hybrid seeds.

Table 7: Most affecting drawback of hybrid seeds

Particulars	Classification	Respondents	Percentage
Drawback of hybrid seeds	[1] Cost	26	**53.06 %**
	[2] Unable to save seeds	10	**20.41 %**
	[3] Dependent on Seed Companies	6	**12.24 %**
	[4] Uneven growth	0	**0 %**
	[5] Resistant to specific disease	1	**2.04 %**
	[6] Special requirements for soil/water	3	**6.12 %**
	[7] Lack of Local Adaptation	3	**6.12 %**

The total number of respondents taken is 49. A survey identifying the drawbacks of hybrid seeds reveals that cost is the predominant concern, cited by 53.06% of respondents. The inability to save seeds for future planting worries 20.41%, suggesting sustainability issues. Dependence on seed companies is problematic for 12.24%, indicating concerns over autonomy and long-term affordability. Other considerations like resistance to specific diseases, special soil or water requirements, and lack of local adaptation constitute 6.12%, pointing to agricultural and environmental challenges. Notably, uneven growth is not reported as a concern, indicating that this may not be a widespread issue with hybrid varieties.

8. The effectiveness of each digital platform in terms of reaching target audiences and promoting seed products: [S1] Not Effective [S2] Slightly Effective [S3] Moderately Effective
[S4] Very Effective [S5] Highly Effective

Table 8: Effectiveness of digital platform

	Variables	**Respondents**				
	Scale	**S1**	**S2**	**S3**	**S4**	**S5**
1	Website	0	0	1	20	28
	Percentage	0 %	0%	2.04 %	40.82 %	57.14 %
2	E-commerce Platform	0	1	16	26	6
	Percentage	0 %	2.04 %	32.65 %	53.06 %	12.24 %
3	Mobile Apps	1	2	16	23	7
	Percentage	2.04 %	4.08 %	32.65 %	46.94 %	
4	Social media	1	1	18	18	11
	Percentage	2.04 %	2.04 %	36.73 %	36.73 %	22.45 %
5	E-mail Marketing	8	30	6	3	2
	Percentage	16.33 %	61.22 %	12.24 %	6.12 %	4.08 %
6	Webinars/Online Workshops	3	8	11	26	1
	Percentage	6.12 %	16.33 %	22.45 %	53.06 %	
7	Online Advertisements	10	14	14	10	1
	Percentage	20.41 %	28.57 %	28.57 %	20.41 %	2.04 %

Website: The survey focused on the efficacy of company websites in promoting seed products to target audiences shows a strong positive response. An impressive 57.14% of respondents consider websites highly

effective, while 40.82% rate them as very effective. A small minority, 2.04%, believe websites to be moderately effective. None of the respondents found company websites ineffective or only slightly effective. This indicates a significant confidence in the role of company websites as effective tools for reaching out to and engaging with their intended market in the seed industry.

E-commerce Platform: The survey on digital platforms for promoting seed products through e-commerce channels strongly indicates their effectiveness. A majority, 53.06%, find them to be 'Very Effective', while 'Highly Effective' is noted by 12.24% of respondents. 'Moderately Effective' is reported by 32.65%, indicating success in reaching target audiences. Interestingly, only a small fraction, 2.04%, perceive these platforms as 'Slightly Effective', and none consider them 'Not Effective'. This data underscores e-commerce platforms' significant role in the contemporary marketing and distribution of seed products.

Mobile Apps: The survey evaluating digital platforms for seed product promotion through Mobile Apps reveals a positive trend: 46.94% of respondents find it very effective, and 14.29% consider it highly effective. Moderate effectiveness is reported by 32.65%, suggesting a substantial reach to target audiences. A minority views it as slightly effective (4.08%) or not effective (2.04%), indicating that while not universal, mobile apps are a potent tool for marketing seeds.

Social media: The survey results underscore the potency of social media as a tool for reaching target audiences and promoting seed products, with a notable 59.18% of respondents rating it as 'Very Effective' or 'Highly Effective'. A significant proportion, 36.73%, find it 'Moderately Effective', while only a small minority of 4.08% consider it 'Not Effective' or just 'Slightly Effective', illustrating its broad efficacy in marketing.

E-mail Marketing: A survey evaluating the impact of e-mail marketing for seed product promotion reveals mixed effectiveness. The majority, 61.22%, find it slightly effective, indicating some success in reaching target audiences. Those considering it moderately effective make up 12.24%, while a smaller portion, 6.12%, views it as very effective, and only 4.08% rate it as highly effective. However, 16.33% deem it not effective, highlighting room for optimisation in this digital strategy.

Webinars/Online Workshops: The survey reveals that digital platforms, specifically Webinars/Online Workshops, are quite effective for promoting seed products. A notable 53.06% of respondents rate them as very effective, with a further 2.04% considering them highly effective. The view of 22.45% is moderately effective, while a smaller segment finds them slightly effective (16.33%). Only a marginal 6.12% deem them not effective, underscoring the overall positive impact of these digital tools in marketing.

Online Advertisements: Survey results on the efficacy of online advertisements for promoting seed products show mixed responses. A significant portion, 28.57%, find them moderately effective, mirroring the sentiment for slight effectiveness. Both not effective and very effective are perceived by 20.41% of respondents, whereas a mere 2.04% believe these ads to be highly effective. This suggests a varied perception of online ad impact in the seed industry.

Descriptive Statistics

Table: Descriptive statistics of variables

Descriptive Statistics							
	N	Minimum	Maximum	Mean	Std. Deviation	Skewness	Std. Error of skewness
1. Gender	49	1	2	1.08	.277	3.153	.340
2. Age	49	1	6	3.35	1.071	.417	.340
3. Average Yield	49	3	5	4.47	.649	-.837	.340
4. Disease resistance	49	1	5	3.96	.999	-1.092	.340
5. Rate of Quality of produce	49	2	5	3.94	.827	-.805	.340
6. Importance of various variables							
Yield Improvement	49	3	6	5.39	.702	-1.091	.340
Quality of produce	49	2	6	4.59	.977	-.618	.340
Cost of seeds	49	1	6	3.94	1.069	-.621	.340
Market demand	49	2	6	4.43	.935	-.500	.340
Access to credit seed purchase	49	1	5	3.29	1.041	-.380	.340

Recommendations from other farmers	49	2	6	4.47	.981	-.118	.340
Availability of hybrid varieties	49	3	6	4.37	.859	.020	.340
Training & extension services	49	2	6	3.78	.963	.621	.340
7. Drawback of hybrid seeds	49	1	7	2.20	1.837	1.663	.340
8. Effectiveness of various variables							
Company websites	49	3	5	4.55	.542	-.618	.340
E-commerce	49	2	5	3.76	.693	-.022	.340
Mobile Apps	49	1	5	3.67	.851	-.572	.340
Social media	49	1	5	3.76	.902	-.372	.340
E mail marketing	49	1	5	2.20	.935	1.326	.340
Online workshops	49	1	5	3.29	.979	-.893	.340
Online advertisements	49	1	5	2.55	1.100	.110	.340

Gender: The mean value of 1.08 with a standard deviation of 0.277 suggests a higher representation of one gender over the other. The scale likely represents a binary gender classification, with the lower number (1) being more prevalent. The sample is gender-imbalanced, predominantly consisting of one gender.

Age: The mean age category is 3.35, with a standard deviation of 1.071, indicating a moderate spread across age categories. The slight positive skewness suggests a minor concentration of respondents in the lower age categories. The respondents are spread across various age categories, with a slight leaning towards younger age groups.

Average Yield: The high mean (4.47) with a moderate standard deviation (0.649) and negative skewness (-0.837) indicates that most respondents experience high yields. Respondents generally report high yields, possibly reflecting the effectiveness of farming practices or seed quality.

Disease Resistance: The mean of 3.96 and standard deviation of 0.999, combined with negative skewness, suggest that respondents generally observe good disease resistance in their crops. Disease resistance is usually perceived as high among the crops of respondents.

Rate of Quality of Produce: The mean of 3.94 with a standard deviation of 0.827 and negative skewness indicates a tendency towards higher ratings for the quality of produce. The quality of produce is generally rated highly by respondents.

Importance of Various Variables: High mean and negative skewness indicate that yield improvement is a highly valued aspect among the respondents. Yield improvement is a critical factor for farmers in the context of hybrid seeds. The relatively high mean suggests that the quality of produce is also a significant factor for farmers. Quality of produce is a major consideration in the adoption of hybrid seeds. The moderate mean indicates that while cost is a factor, it may not be as critical as yield or quality. Cost is an important but not the predominant factor affecting farmers' decisions. The high mean reflects the importance of market demand in influencing farmers' choices. Market demand plays a significant role in the decision-making process for hybrid seed adoption. The lower mean suggests that while important, access to credit is not as crucial as other factors. Access to credit is a factor but not the most influential one in hybrid seed adoption. The high mean indicates that farmers value peer recommendations highly. Recommendations from other farmers are a strong influencer in the adoption of hybrid seeds. The high mean suggests that the availability of different hybrid varieties is important. Availability is a key factor in the decision to adopt hybrid seeds. This moderate mean indicates a significant but varied importance of training and extension services. Training and extension services are important, but their influence varies among farmers.

Drawbacks of Hybrid Seeds: The low mean of 2.20 and high positive skewness (1.663) indicate that respondents generally perceive fewer drawbacks of hybrid seeds. There is a general perception among respondents that hybrid seeds have fewer drawbacks.

Effectiveness of Digital Platforms: The high mean of Company Websites indicates strong effectiveness, and the negative skewness suggests that most responses are concentrated on the higher end, with fewer respondents rating it lower. Company websites are highly effective in the agriculture sector, with most respondents acknowledging their significant positive impact. A moderately high mean of E-commerce implies good

effectiveness, with skewness indicating a slight concentration of responses towards the higher end. E-commerce is moderately effective and generally viewed positively, but there may be room for improvement to enhance its impact. The mean of Mobile Apps suggests moderate effectiveness, and the skewness indicates a mild concentration of higher ratings. Mobile apps are moderately effective but may need enhancements for better user engagement and functionality. Similar to e-commerce, social media has moderate effectiveness with a slight tilt towards higher ratings. Social media is a moderately effective tool for communication and marketing, with potential for greater impact.

The low mean of e-mail marketing indicates limited effectiveness and positive skewness, suggesting a concentration of lower ratings. E-mail marketing is less effective in the agriculture sector, potentially due to issues like overuse or lack of personalisation. A moderate mean with slight negative skewness implies that while online workshops are somewhat effective, there is a small tendency towards higher ratings. Online workshops have moderate effectiveness but could be improved to meet the needs of the agricultural community better. The low mean suggests limited effectiveness, and the positive skewness indicates that more respondents tend to rate it lower. Online advertisements are not very effective in the agriculture sector, possibly due to issues like relevance or ad saturation.

Correlation Statistics

Correlations

		Average yield	Disease resistance	Rate of Quality of produce	Yield Improvement	Importance of Quality of produce
Average yield	Pearson Correlation	1	-.002	.249	.461**	.539**
	Sig. (2-tailed)		.989	.085	<.001	<.001
	N	49	49	49	49	49
Disease resistance	Pearson Correlation	-.002	1	.451**	.112	.217
	Sig. (2-tailed)	.989		.001	.443	.134
	N	49	49	49	49	49
Rate of Quality of produce	Pearson Correlation	.249	.451**	1	.401**	.536**
	Sig. (2-tailed)	.085	.001		.004	<.001
	N	49	49	49	49	49
Yield Improvement	Pearson Correlation	.461**	.112	.401**	1	.752**
	Sig. (2-tailed)	<.001	.443	.004		<.001
	N	49	49	49	49	49
Importance of Quality of produce	Pearson Correlation	.539**	.217	.536**	.752**	1
	Sig. (2-tailed)	<.001	.134	<.001	<.001	
	N	49	49	49	49	49

**. Correlation is significant at the 0.01 level (2-tailed).

According to the above correlation coefficients, it is found that **average yield** has a moderate positive correlation with yield improvement ($r = 0.461$, $p < .001$) and the importance of quality of produce ($r = 0.539$, $p < .001$). **Disease resistance** shows a moderate correlation with the rate of quality produce ($r = 0.451$, $p = .001$) and is not significantly correlated with other variables. **The rate of quality of produce** has a moderate to strong correlation with yield improvement ($r = 0.401$, $p = .004$) and a strong correlation with the importance of quality of produce ($r = 0.536$, $p < .001$). **Yield improvement** is strongly correlated with the importance of quality of produce ($r = 0.752$, $p < .001$). Therefore, all correlations mentioned above are statistically significant at the 0.01 level (2-tailed), except for the relationship between Disease Resistance and Yield Improvement and Disease Resistance and the Importance of Quality of produce, which are not statistically significant.

INJ INTERNATIONAL NEUROUROLOGY JOURNAL

Regression Analysis

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.280[a]	.078	.038	.636

a. Predictors: (Constant), quality of produce, Disease resistance

ANOVA[a]

Model		Sum of Squares	Df	Mean Square	F	Sig.
1	Regression	1.582	2	.791	1.954	.153[b]
	Residual	18.622	46	.405		
	Total	20.204	48			

a. Dependent Variable: Average yield

b. Predictors: (Constant), quality of produce, Disease resistance

Coefficients[a]

Model		Unstandardised Coefficients		Standardised Coefficients		
		B	Std. Error	Beta	t	Sig.
1	(Constant)	3.869	.484		7.989	<.001
	Disease resistance	-.093	.103	-.143	-.904	.371
	Quality of produce	.246	.124	.313	1.977	.054

a. Dependent Variable: Average yield

As per the above table, the regression analysis results reveal some intriguing insights into the relationships between average yield, disease resistance, and quality rate in hybrid seeds. The R-squared value of 0.078 indicates that approximately 7.8% of the variation in average yield is explained by these two factors, suggesting that other variables not included in the model may also significantly influence yield. The negative coefficient for disease resistance, although not statistically significant ($p = 0.371$), implies a complex and non-linear relationship with an average yield, suggesting that higher disease resistance does not straightforwardly translate to increased yield. This could be due to a variety of agronomic or environmental factors not captured in the model. The quality rate shows a positive coefficient (0.246) with a borderline significance (p = 0.054), hinting that higher-quality seeds may lead to better yields. However, this relationship is not definitively conclusive in this analysis. The near-significance suggests a potential trend worth investigating further. Overall, the results underscore the nuanced and multifaceted nature of factors influencing yield in hybrid seeds, highlighting the need for a comprehensive approach to agricultural research and seed development.

ANOVA TEST

ANOVA						
		Sum of Squares	Df	Mean Square	F	p/ Sig.
Company websites	Between Groups	1.322	1	1.322	4.856	.032
	Within Groups	12.800	47	.272		
	Total	14.122	48			
E-commerce	Between Groups	1.111	1	1.111	2.379	.130
	Within Groups	21.950	47	.467		
	Total	23.061	48			
Mobile Apps	Between Groups	3.714	1	3.714	5.620	.022
	Within Groups	31.061	47	.661		
	Total	34.776	48			
Social media	Between Groups	1.111	1	1.111	1.376	.247
	Within Groups	37.950	47	.807		
	Total	39.061	48			
E mail marketing	Between Groups	.381	1	.381	.431	.515
	Within Groups	41.578	47	.885		

DOI: 10.5123/inj.2023.4.in115
ISSN:2093-4777 | E-ISSN:2093-6931
Vol. 27 Iss. 4 (2023)

	Total	41.959	48			
Online workshops	Between Groups	.939	1	.939	.979	.327
	Within Groups	45.061	47	.959		
	Total	46.000	48			
Online advertisements	Between Groups	.878	1	.878	.721	.400
	Within Groups	57.244	47	1.218		
	Total	58.122	48			

The above table of ANOVA analysis from the document assesses the effectiveness of various digital platforms in a specific context, possibly related to marketing or communication strategies. The platforms analysed are company websites, e-commerce, mobile apps, social media, e-mail marketing, online workshops, and online advertisements.

Company Websites: Showed a significant effect ($F = 4.856$, $p = .032$), indicating their effectiveness differs notably from other platforms.

E-commerce: While showing some variance ($F = 2.379$), it's not statistically significant ($p = .130$), suggesting its effectiveness is comparable to other platforms.

Mobile Apps: Demonstrated a significant difference in effectiveness ($F = 5.620$, $p = .022$), indicating they stand out compared to other platforms.

Social Media: Presented a lower F value (1.376) and a higher p-value (.247), indicating no significant difference in effectiveness.

E-mail Marketing: Showed very low effectiveness compared to other platforms ($F = .431$, $p = .515$).
Online Workshops: Similar to e-mail marketing, it did not show significant effectiveness ($F = .979$, $p = .327$).

Online Advertisements: Also displayed no significant variance in effectiveness ($F = .721$, $p = .400$).
Therefore, it is concluded that the analysis suggests that certain digital platforms like company websites and mobile apps significantly differ in their effectiveness compared to others. In contrast, platforms like social media, e-mail marketing, online workshops, and online advertisements do not show a significant difference in effectiveness. This implies a need for strategic focus and potential re-evaluation of certain digital channels in the context in which they are being used.

Hypothesis Test Results

First Hypothesis Test result

According to the correlation table, the correlation is almost zero (-0.001968), indicating no linear relationship between yield and disease resistance. A positive correlation (0.248868) suggests a slight association between higher yield and better quality. A moderate positive correlation (0.450829) indicates that better disease resistance is associated with higher quality. The descriptive statistics show that hybrid seeds are rated highly across all three parameters (yield, disease resistance, and quality). This supports the hypothesis that hybrid seeds are associated with agronomic benefits.
However, the correlation analysis provides a more nuanced view:

There is a slight positive correlation between yield and quality, suggesting that higher yields might be somewhat associated with better quality produce.
The moderate positive correlation between disease resistance and quality indicates that disease resistance is an important factor for the overall quality of the produce.

Second Hypothesis test result

As the significant ANOVA results, we can reject the null hypothesis (H0). This means there are significant differences in how effective different digital platforms are perceived for promoting seed products. This supports the alternative hypothesis (H1) that certain digital platforms (like company websites, e-commerce platforms, and social media) might be significantly more effective than others (like mobile apps, e-mail marketing, online workshops, and online advertisements). However, to know which specific platforms are more effective, post-hoc tests are necessary. The analysis supports the notion that there is a significant variance in the perceived effectiveness of different digital platforms in promoting seed products.

Conclusion, recommendations, directions, implications and limitations

Conclusion

1) The analysis indicated that hybrid seeds are generally perceived positively by farmers, with high average yields, good disease resistance, and high-quality rates. This suggests that hybrid seeds offer significant agronomic benefits over traditional varieties. However, the correlation analysis revealed that while these benefits are clear, the relationships among them are complex. For instance, there was a moderate correlation between disease resistance and quality. This complexity highlights the multifaceted nature of agronomic benefits associated with hybrid seeds.
2) The analysis revealed significant differences in the perceived effectiveness of various digital platforms used for promoting seed products. Specifically, company websites, e-commerce platforms, and social media were found to be more effective compared to other channels such as mobile apps, e-mail marketing, and online advertisements. This suggests a strategic focus on these platforms could be more beneficial for businesses in the seed industry. The significant variance in effectiveness ratings across platforms indicates that while some digital channels are highly valued, others may require re-evaluation or different approaches to enhance their effectiveness.

Recommendations

The study focused on two pivotal aspects: evaluating the agronomic benefits of hybrid seeds and assessing the effectiveness of various digital platforms in the agricultural sector. Analysis revealed that farmers perceive hybrid seeds positively, noting substantial benefits in terms of yield, disease resistance, and produce quality. However, the relationship between these benefits is complex. In terms of digital platform effectiveness, company websites, e-commerce platforms, and social media have emerged as the most effective channels for promoting seed products, significantly surpassing mobile apps, e-mail marketing, and online advertisements in effectiveness. These findings suggest that while hybrid seeds offer notable agronomic advantages, understanding their multifaceted benefits is crucial for farmers. Simultaneously, the seed industry should prioritise and tailor strategies for the most effective digital platforms to enhance marketing outreach and customer engagement, keeping an eye on evolving digital trends and the diverse needs of their audience. This dual focus on agronomic innovation and digital marketing optimisation is key to advancing farmer engagement and success in the modern agricultural landscape.

Directions In Use

Further research should focus on enhancing the specific attributes of hybrid seeds that farmers use, such as disease resistance and yield quality value. Explore new hybrid varieties that could address the current gaps, like cost-effectiveness and specific climate adaptability. Develop educational initiatives to inform farmers about the multifaceted benefits of hybrid seeds. This should include information on best practices for cultivation and management to maximise yield and quality. Explore new and innovative ways to use less popular digital channels to reach wider and diverse audiences. Regularly gather feedback from farmers to continuously improve both the product offerings and the marketing strategies. Leverage analytics across these platforms to gain a comprehensive view of customer engagement and preferences. Perform regular market analysis to stay informed about industry trends, competitor strategies, and changing customer needs.

Implications For Marketers And Dealers

The data analysis reveals significant differences in the effectiveness of various digital platforms, which is crucial for seed marketers and dealers. Platforms with higher effectiveness ratings are prioritised for marketing and customer engagement. For instance, if "Company Websites" are rated more effective than "E-commerce," efforts should focus on enhancing website features and user experience. Similarly, the similarity in effectiveness between "Mobile Apps" and "Social Media" suggests an integrated approach could be beneficial. These insights enable seed marketers and dealers to allocate resources more strategically, tailoring their digital presence to platforms that resonate most with their customers, thereby optimising outreach and potentially increasing sales efficiency.

Limitations

Questionnaire-related issues include response bias, varying question interpretations, the potential influence of phrasing and order, non-response bias, and a lack of qualitative insights. The analyses' limitations involve questions about sample representativeness, the inability to establish causality, reliance on specific statistical assumptions, and the potential oversimplification of complex data through binary comparisons. The

questionnaire used for assessing digital platform effectiveness in seed marketing and the subsequent ANOVA and T-test analyses have notable limitations. Additionally, the questionnaire and analyses do not fully account for the dynamic nature of digital platforms and evolving market trends, highlighting the need for a comprehensive, contextually aware approach.

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ANNEXURE

An effective survey questionnaire was used to gather accurate and helpful information. The questionnaire was designed "to evaluate the agronomic benefits of hybrid seeds and understand farmers' adoption preferences over traditional varieties. "To assess which digital platforms are predominantly used by customers effectively.

Name of respondent: .....

Address:……..…….

Contact No :.....

Gender: [1] Male [2] Female

Age: [1] 18-24 [2] 25-34 [3] 35-44 [4] 45-54 [5] 55-64 [6] 65 and over

1. On average, how do the yields from hybrid seeds compare to traditional varieties?

[1] Significantly lower [2] Slightly lower [3] About the same [4] Slightly higher [5] Significantly higher

2. Have you noticed any improvement in disease resistance with hybrid seeds?

[1] No resistance [2] Less resistance [3] No difference [4] Slightly improved resistance [5] Significantly improved resistance

3. How would you rate the quality of produce from hybrid seeds?

[1] Poor [2] Fair [3] Good [4] Very good [5] Excellent

4. Please rate the importance of the following factors in your decision to adopt hybrid seeds on a scale from [S1] Not important [S2] Low important [S3] Slightly important [S4] Moderately important [S5] Very important [S6] Extremely important

	Factors	S1	S2	S3	S4	S5	S6
1.	Yield Improvement:	1	2	3	4	5	6
2.	Quality of Produce:	1	2	3	4	5	6
3.	Cost of Seeds:	1	2	3	4	5	6
4.	Market Demand for Hybrid Produce:	1	2	3	4	5	6
5.	Access to Credit for Seed Purchase:	1	2	3	4	5	6
6.	Recommendations from Other Farmers:	1	2	3	4	5	6
7.	Availability of Hybrid Varieties:	1	2	3	4	5	6
8.	Training and Extension Services:	1	2	3	4	5	6

5. Which of the following is the most affecting drawback of hybrid seeds?

[1] Cost [2] Unable to save seeds [3] Dependent on Seed Companies [4] Uneven growth [5] Resistant to specific disease [6] Special requirements for soil/water [7] Lack of Local Adaptation

6. On a scale of 1 to 5, please rate the effectiveness of each digital platform in terms of reaching target audiences and promoting seed products: [S1] Not Effective [S2] Slightly Effective [S3] Moderately Effective [S4] Very Effective [S5] Highly Effective

	Factors	S1	S2	S3	S4	S5
1.	Company Website	1	2	3	4	5
2.	E-commerce Platform	1	2	3	4	5

ISSN:2093-4777 | E-ISSN:2093-6931
DOI: 10.5123/inj.2023.4.in115
Vol. 27 Iss. 4 (2023)

3.	Mobile Apps	1	2	3	4	5
4.	Social Media	1	2	3	4	5
5.	E-mail Marketing	1	2	3	4	5
6.	Webinars/Online Workshops	1	2	3	4	5
7.	Online Advertisements	1	2	3	4	5
8.	Others(Please specify)……	1	2	3	4	5

ISSN:2093-4777 | E-ISSN:2093-6931
DOI: 10.5123/inj.2023.4.in115
Vol. 27 Iss. 4 (2023)