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A Technological Perspective of Weeds in Agriculture

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ABSTRACT
The need forincreased and sustainable agricultural production is directly associated with the increased global population andlimited agricultural land availability. Dependencies on weather, climatic conditions, and factors like weeds, diseases, pests, or any of these combinatorial issuesplay a significant role in the agricultural cropyield. Disease and pest controls during cultivation are relatively straightforward, but weed control has extensive challenges since it coexists with crops as a contender of the same soil nutrition, apart from the common favorable environment during the desired plant growth period. Weeds are detrimental to crop, but it is manageable to protect through various biological, chemical, cultural, or physical mechanisms and compliant with ecological methods.Literature revealsthat theweed control methods have few shortcomings, which influence theoverall crop production. However, the advent of precision technology in agriculture will provide a way to overcome such drawbacks.This present review article highlights the literature, and various technological methods to control weeds with precision. The studyalso highlights a brief history of the need and development of technology involved in weed management, with a thrust on prevailingweed control challenges in India and provisionof futuristics planning to support thesmall farmers as end-users!
Key Words *IWM, Pesticides, GVP, Herbicide, VRT*
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INTRODUCTION

In the earlier days, the population countwas low, with the availability of abundant agricultural land for the conventional crop growing system to meet society's needssatisfactorily. With passage oftime, the world population increased exponentially,and the cultivatable land area shrunk with urbanization. It used to lead to hunger and famine as food grain growth per year was poorer than needed. Indian agricultural development in the era 1950 – 60s was conventional and not backed by any improved processes, causing repeated uncertainty in agricultural growth. However, from the early sixties,with proper government initiatives, India could achieve a Green Revolution (GR) by producing high-yielding varieties of rice and wheat to increase food grainproduction. The GRextending from the mid-sixties to mid-seventies transformed India from a food-deficient country to a leading agricultural nation. While the initial focus of GR was to expand farming areas, soon awareness and actionsstarted building to increase crop yields through the use of fertilizers, improved seed quality, chemical pesticides,etc.

Even since Green Revolution, Indiacontinued its sustainable year-on-year production growth rateand higher yieldsin agriculture and associated sectors.In 2020-21, itcontributed20.19% of Gross Value Product (GVP)(Fig.1)as a measure of whole economic output among three key economic sectors (services, industry, and agriculture)[1].

The agricultural GDP growth rate in India over from last five years (2015-16 to 2019-2020)[2] is shown in Fig. 2.Growth in this sector recorded fluctuating trends over the last few years. There can be multiplefactors for such a trend. One possiblereason to attribute is decreasedsoil responses to excess or inappropriate use of chemical fertilizers over some time. In 2020-21, despite Covid 19 impacts, GVA for agriculture recorded positive growthof 20.19% (, Fig. 1).

Table 1:

	GVA in 2020-21	GVA share (%)
1	Agriculture Sector	20.19%
2	Industry Sector	25.92%
3	Services Sector	53.89%
		100%

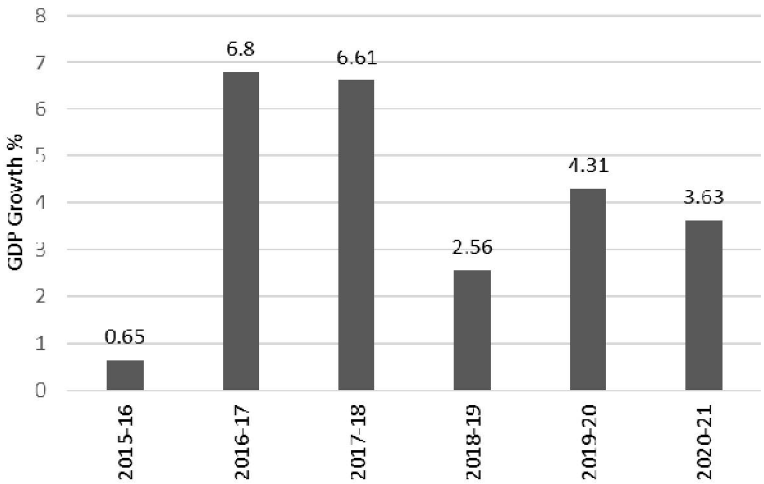


Fig 2. Agriculture Sector - GDP Growth of India

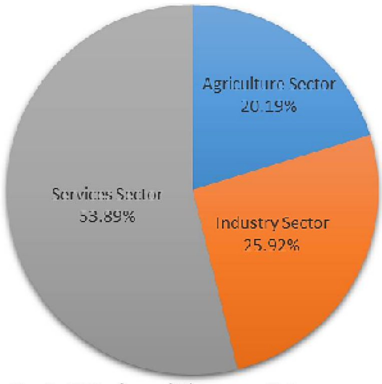


Fig. 1: GVA share (%) among 3 Keys Economic Sectors in India (2020-21)

Such a feat needs broader people's participation and contribution. About 54.60% of the total population in India were directly or indirectlyinvolved in agriculture as per the last census in 2011 [3],indicating the significance of this sector in a socio-economic context.

Crop production, limited by declining agricultural land availability due to fast urbanization, has to factor in weather & climate as natural dependencies and other factors like weeds, diseases, pests, rodents, or any other issues during the cultivation period.

The agricultural yield factor (ratio of crop produced and associated cultivating land) is influenced by weeds as a competition to crop, being highly invasive and outcompeting. It is culturally backed by a famous saying from the Women's group, Zimbabwe, *"Without weeding do not expect any harvest. The back has to ache to conquer the weeds!".*

A study in 2014 by Tata Strategic Management Group reported more crop losses due to weed infiltration (34%) when compared with factors like insects (26%), diseases (26%), rodents (6%), and others (8%) (Fig.3) establishing the criticality of weeds. It is a piece of vital information to generate awareness among the farmers.

The present review paper is about weed control practices improvised by experimental researchers in India and technological advancements across the globe to achieve higher agricultural yields. It is in tune with the set policy target of the Government of India to double farmers' income. Technological advances in weed control have few challenges of acceptance and deployment in the Indian context to align as an affordable solution to farmers and cultural acceptance as we advance the way forward.

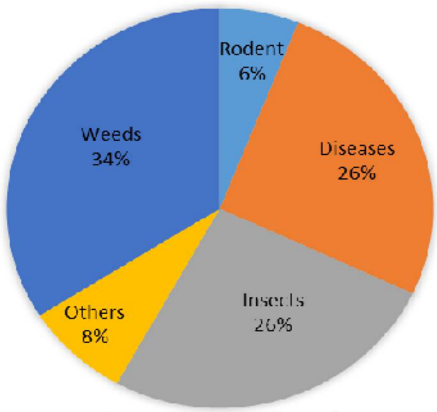


Fig. 3: Criticality of weeds

Weed Control Practices And Researches In India

Weeds usually grow from the previous season seeds (annual) or can regrow (perennial) from dormant roots, underground stems, tubers, rhizomes, etc. Classifying weeds based on their lifecycle (annual or perennial), origin (indigenous or not), morphology (shoot or root), habitat (terrestrial or aquatic), soil types (black soil, red soil, etc.),or association with a particular crop help to understand weed characteristics for its control, spread and separating from the crop. Invasive weeds can threaten biodiversity due to their allelopathic effect by producing biochemicals that influence the growth and germination of adjoining plants.

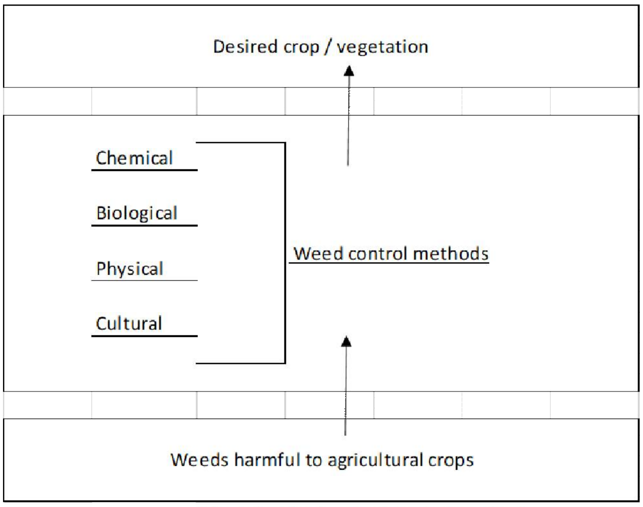


Fig. 4: Available weed control methods

Weed management conceptually prevents weeds from growing or spread through cultural, physical, biological, and chemical methods. The adjoining diagram (Fig. 4) depicts a representative situational and combinational hierarchy of these weed control methods.

For decades, using herbicides are a traditional and successful practice of chemical applications in weed control [4]. These are applied on the soil surface so that weeds germinating on top or surface layers are killed due to the herbicide's incidental absorption. For perennial weeds, herbicides are injected as a sub-surface application into lower soil layers at several points to reach underground stems, tubers, dormant roots, rhizomes and kill them. Based on a statistical estimate of an amount (in mg) of toxicant per kg of bodyweight that is fatal to kill 50% of a large population of test animals (say, rats); World Health Organization (WHO) classified insecticides, hence herbicides as extremely, highly, moderately and slightly hazardous [5]. Higher the toxicity more detrimental for health and system ecology. Regulatory controls and restrictions are imposed from time to time, keeping health, ecology, etc., in consideration.

In chemical applications, the evolution of weed resistance to multiple herbicides opened up studying the genetics of weed adaptation under the biological control of multiplegene inheritance[6]. Apart from using herbicides as chemicals, foliar applications provide fertilizer or chemical nutrients by spraying selectively on crop leaves, thereby depriving weeds of such nutrition.

Biological methods deploy specific insects, pathogens, or other animals acting as bioagents to invadeweeds and preventtheir growth or kill them. Traditionally, biological controls are effective in reducing weeds but not in eradicating them.

Physical methods apply physical forces through human or animal, or mechanical tools to pull out and kill weeds. Hand-weeding, hand-hoeing, digging, burning ... are simple examples widely practiced to control weeds depending up on weed and crop situation during a cultivation period.

Cultural practices in weed control helpto create a favorable crop condition. For example, regular cleaning and maintaining the sanity of crop area through tillage, irrigation, adding fertilizer or nutrients closer to plants oneither side, crop rotation, etc.,are some popular cultural practices in weed control. In addition, the removal of aquatic weeds is a preventive process to avoid water loss, weaker water flows and improve the physical & chemical characteristics of hydro soil and water[7].

Soon after sowing seeds in the field, weeds also start growing, competing with the crops.Integrated Weed Management (IWM) is a situational approach to manage weeds in the fields by incorporating techniques or available methods as and when needed. It makes the best use of the prevailing situation in a crop growing season. While chemical & biological processes are significantly crucial among them, prevention is practiced widely in India through labor-intensive physical processes based on weed and crop situations. The use of technical gadgets can be alternatives to some of these labor-intensive physical methods in weed control.

Researchers in India experimentedwith different weed control techniques for bettercontrol and reducethe use ofherbicides,considering the importance of food safety and soil quality. It is observed that physical weed control mechanisms, precise inter andintra-row cultivation,etc.,can supplement reduced use of chemicals.

Central Research Station of College of Agriculture, Bhubaneswar,experimentedwith studyingthe performance of nutrients and microbial status of soil at the end of two consecutive cropping cycles using combinations of different weed management practices and varying herbicide concentrations. Experimental data indicated improvedsoil quality (microbial population of bacteria, fungus, actinomycetes,and dehydrogenase activity). It is influenced by a combination of weed management practices and nutrients in a rice-maize cropping system[8].

A field experiment at Anand Agricultural University (Gujarat) on irrigated wheat during two successive rabi seasons using combinations of herbicide treatments yielded a lower weed density and higher wheat grains in post-emergence application treatment of combinatorial herbicides [9].Analysis of two years of rice production data at Agricultural Research Station, Ragolu (Andhra Pradesh), used a combination of

applying green manure, conoweeding, and need-based hand weeding. It indicateda higher rice grain yield with an increased benefit to cost ratio [10].
A study conductedonallelopathic compounds by Tabuk University – Saudi Arabia used natural herbicides on seed germination and recorded theirweed control potential during the seedling development of weed species[11]. Such natural usages are ecofriendly and can supplement parallel approaches in weed control, possible by identifying compounds that inhibit seed germination, prevention of unwanted production and growth.
A weedy check treatment in a field experiment conducted by an agronomy research farm in Kumarganj, Ayodhaya,used a combination of nitrogen sources and weed control treatments on turmeric at successive stages of crop growing years;recorded higher yield attributes of plant height, leaf area index (LAI) and lower value of weed density, dry weight[12].Similar research of weed influence on the growth of a maize variety cultivated by selective breeding, under various weed control mechanisms, recorded a reduced weed LAI and biomass dry weight during 6 – 8Weeks After Planting (WAP)[13].
A pot experiment at Zonal Agriculture Research Station, Kalaburagi (Karnataka), studied the influence of weed management by allelopathy practices on nutrient status using plant extracts with 50% reduced herbicide in maintaining soil fertility and productivity over a more extended period. The resultant outcome indicated a more productive, sustainable growth directly or indirectly [14].
The experimental results of pre-emergence (killing weeds before sprout) herbicide of rice crop could be effective on weed control among practical options like no weed control, manual weeding, pre-emergence, and post-emergence herbicide weed control treatments [15].A similar study of an irrigated blackgram at the College of Agricultural Technology, Kullapuram (Tamil Nadu), was completed on the effectsfrom pre-emergence (PE) and early post-emergence (EPoE) herbicides with different weed managementpractices. ThePE herbicide application was an effective and economical weed management practice based oncrop growth, improved weed control, and higher crop yield [16].
In an indicative experiment, an indigenous tractor-operated seed, fertilizer,and drill-cum-weedicide applicator was developed and evaluated for its techno-economic feasibility at Central Demonstration Farm, Wani-Rambhapur - Maharashtra. The effect of applying weedicide using an improvised tool helped timely spraying on the crop with reduced time than manually spraying by the farmers [17]. Furthermore, reviewing existing mechanical weeders to know their merits and demerit may help fund additional technical support needed to meet the farmers' needs.
Experiments and continued effort by researchers will usher to control the dynamism in weedbiology and improving techniques, tools, and processes for the benefit of farmers and managed agricultural yields. Furthermore, data and results from such experiments are essential to rolling back to the field for appropriate suitability of weed control approaches mapped to crop, climate (temperature, humidity ...), and soil conditions (microbial contents ...), etc.

Use Of Herbicides In Weed Control

Herbicides used in chemical methods characterized by their efficiency in weed control improved cost-effectiveness during agricultural crop production. Herbicides can be both inorganic and organic. While inorganic herbicides are synthetically created in a lab, organic ones are made from chemicals occurring in nature. Organic herbicides with low toxicity levels break down quickly and have minimum residual effects, providing environmental and health benefits to both the plant and the soil. Herbicides can also be classified based upon their time of application (pre-emergence, post-emergence), application methods (foliar, root absorbed), chemical groups, and modes of action on plants.
Agricultural growth witnessed herbicide consumptionmultiplying withtime. The demand is rising for products that work on low doses, high potency with broad-spectrum weed control.Nearly 270 herbicides were introduced globally between 1936 – 2012. A count of herbicide chemicals primarily inorganic and used as weed management practices is plotted in Fig. 5. While there was a spurt in developing new chemicals during the sixties till the eighties, not many new chemicals added post-nineties, indicating an overall downward trend in adding new ones with elapsed time.

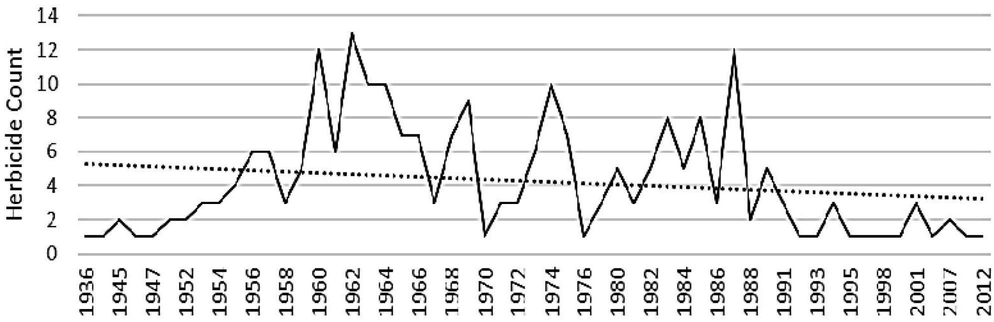


Fig. 5: Herbicide counts vs. Year of Introduction
Source: Pesticide Properties DB, University of Hertfordshire, 2015

In India, herbicides used to be imported way back in the 1960s, primarily for tea plantations. The multinationals then controlled the herbicide markets. Not much of its detailed usageswere found documentedin those days.Herbicides,characterized by their efficiency and improved cost-effectiveness, drew the attention of farmers with the increase in labor cost for manual weed removal. Transformed farmers switched to using herbicides to the best possible extent. The Sooner its overall consumption increased manifolds. There are nearly 700 formulations of herbicides now available in the Indian market to cater weed control to crops of different nature. As of 2015, around 60 technical herbicides and 17 combination herbicides registered for use in India. Some herbicides previously registered for use were later debarred from further agriculture due to their high toxicity and environmental impact [18]. The Major varieties of classified herbicides used in India during 1990 – 2010are captured in Table 1(Source: FAOSTAT).

Table 1: Herbicides used in tones during 1990 - 2010 in India.

Year	Amides	Bipiridils	Dinitroanilines	Phenoxy hormone products	Triazines	Urea derivates	Other	Total
1990				791	275	1804	2951	5821
1991				686	285	1881	3151	6003
1992				750	277	2290	4120	7437
1993	1113			629	310	2307	2234	6593
1994	1919	46	95	612	472	2568	1098	6810
1995	2271	25	94	467	207	2490	566	6120
1996	2596	35	114	621	353	2657	882	7258
1997	2644	41	112	609	350	2674	562	6992
1998	2647	62	164	659	452	2662	835	7481
1999	2598	113	161	680	424	2685	819	7480
2003			213			2842	4445	7500
2004			115			2333	2706	5154
2005			289			1447	5223	6959
2006			82			2251	3971	6304
2007			98			1428	2596	4122
2008			81			1217	2276	3574
2009			49			1215	2956	4220
2010			71			1834	4430	6335
Total	15788	322	1738	6504	3405	38585	45821	112163

In 2020, nearly 140 manufacturers produced herbicides (for example, algicides, defoliant, amide, arsenical, dinitroaniline, pyridazine, and thiocarbamate)in India. Maharashtra, Gujarat, Delhi, Tamil Nadu were front linerstatesfor such herbicide productions[19].

Fig. 6 shows the overall herbicide consumption trend in India captured between 1990 – 2010.

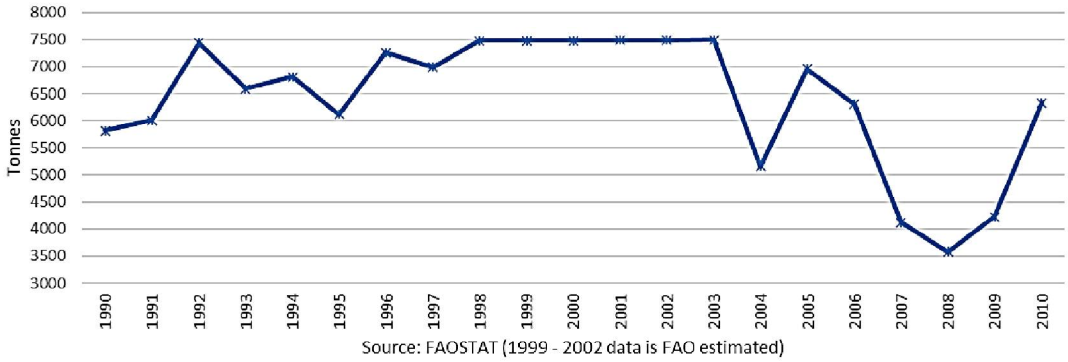


Fig.6: Herbicide usage pattern in India during 1990 - 2010

In agricultural context,insecticides, herbicides, bactericides, fungicides, and rodenticides - allcollectively called pesticides. Thus,the herbicides are a subset of pesticides. The use of aggregated pesticides in the early nineties was much higher in India. Fig. 7 shows its downtrend consumption between 1990 to 2010 though herbicides consumptions were range-bound during the same period.

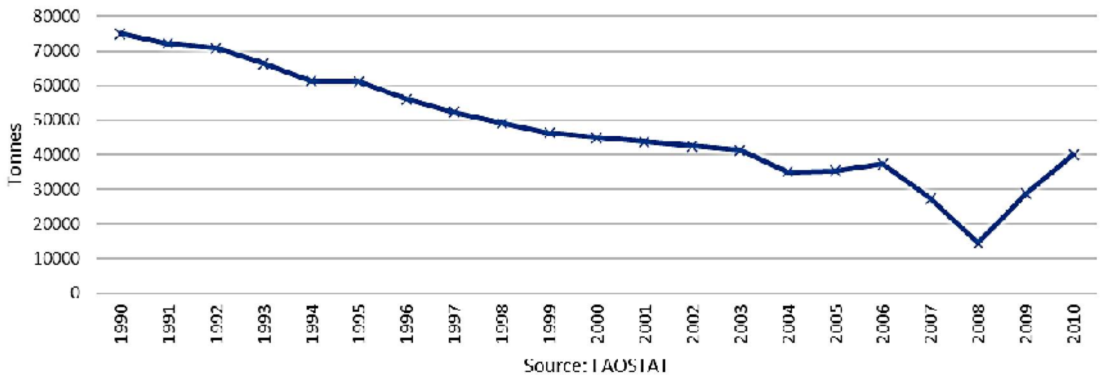
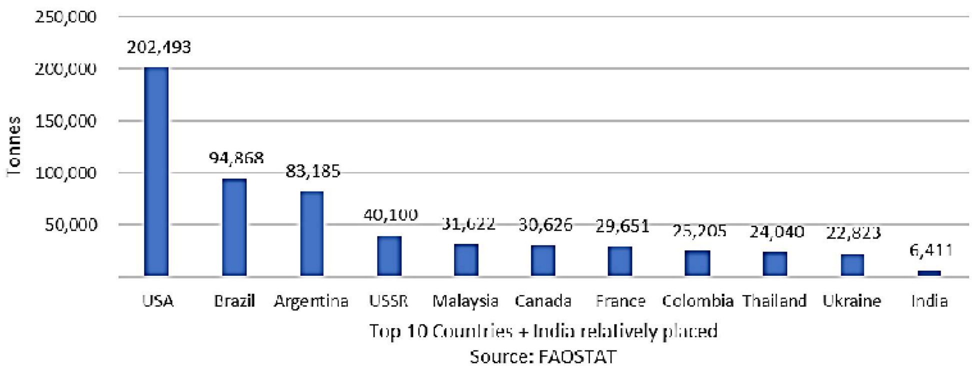


Fig. 7: Aggregated (1990 - 2010) Pesticide (total) use trend in India

Aggregated herbicide usages during 1990 – 2010,shown in Fig. 8,have relative positions of the top 10 countries. India is added to the same list for a denoting relative position (way below top 10 countries) in herbicide consumption (tones) during the same period.

Fig. 8:



Aggregated (1990 - 2010) top 10 herbicide users in the world.

Table 2 captures comparative data on top herbicides and pesticide-consuming countries along with indicative percent use of (herbicide/pesticides).

Table 2 (Source: FAOSTAT)

Country	Pesticides Use (tones)	Herbicides (tones)	(Herbicides/Pesticides) %
USA	407,052	202,493	49.7%
Brazil	166,048	94,868	57.1%
USSR	89,200	40,100	45.0%
France	87,806	29,651	33.8%
Colombia	54,770	25,205	46.0%
India	47,698	6,411	13.4%

Figures 9 and 10 show the profiling of harvested land and crop production in India from 1961 to 2019 for rice and wheat, respectively, as representative crops (Source: FAOSTAT). The growthsaligned with the onset of the green revolution,used fertilizers, pesticides, and herbicides to improve production and yield.

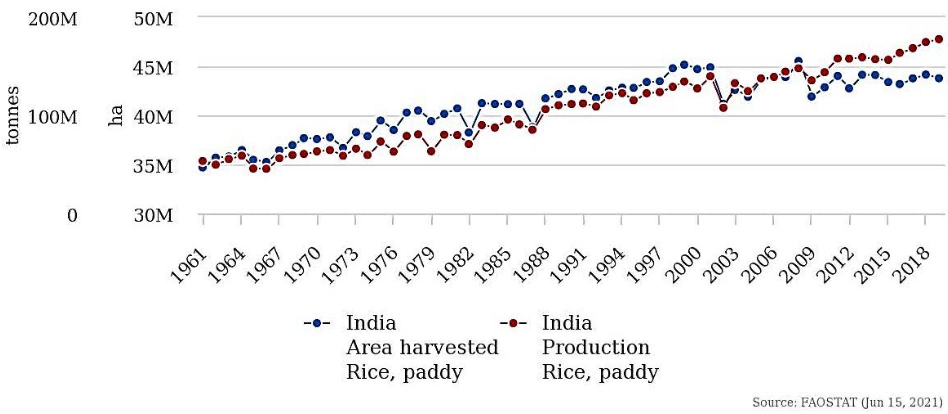


Fig. 9: Production / Yield quantities of Rice in India during 1961 to 2019

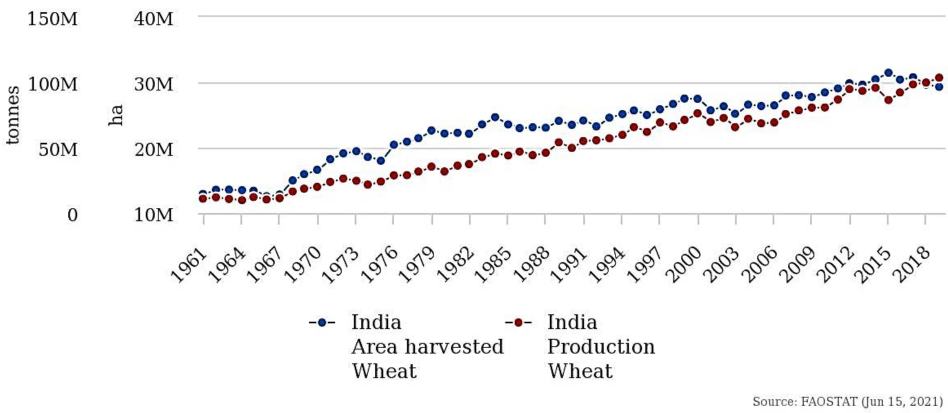


Fig. 10: Production / Yield quantities of Wheat in India during 1961 to 2019

Technological Advancements

Most small farmers usually pluck weeds manually from thefield, or they spray herbicides using manual backpacks. Their weed removal tools include brush cutter, trimmer, power weeders, etc. Backpacksprayers are vulnerable due to lack of precision in quantity needed, health concerns of persons involved in spraying,etc. Existing practices have low yields in the absence of appropriate technology for precision usage. Limited herbicide choices and increased costs in weed management costs added challenges to overall crop productivity hence profitability. With an intent to double the farmers' earnings set by the Government of India, smart agriculture with intelligent technologies is essential to bring a difference.

IoT-based innovative applications add revolution to traditional weed control methods, supported by GPS-based remote-controlled robots with smart onboard sensors,Wi-Fi, camera, microcontroller, and raspberry pi as hardware platforms [20]. Data from soil sensors, temperature &humidity sensors, air quality sensors, sensors capturing video and photographs can be monitored near real-time and processed for decision making.

Robotics in weed management supported by computer vision and AI triggers robotic actions targeting the weeds with precision. A programmable expert system can control and manage its activities automatically [21]. An automated decision-making robot enabled by Variable Rate Technology (VRT) can apply herbicides at variable rates without manually changing equipment. VRT enablesVariable Rate Applications (VRA) of materials to a given landscape based on data collected by sensors, maps, and GPS through a Variable Rate Controller (VRC). The system canensuresustainability and environmental safety[22] by controlled use of herbicides.

Combined electronics and mechanical engineering (mechatronics in precise)with image recognition and other machine learning applicationscan work as an autonomous machine for weed control in the field.Statistical toolsandanalysis of captured images by guided drones can help maintain a balance between herbicide spray and weed removal by a trained robot withsensorsmounted on it [23].

Use of robotics in weed control on hitting precision targets need spatial localization (longitude-latitude – latitude) of weeds (recognizing and distinguishing weeds from crops) and precision application of some weed growth limiting activity by precision herbicide spray in Site Specific Weed Management (SSWM) through efficient weed maps by Unmanned Aerial Vehicles (UAV). It can monitor weeds and provide decision-supporting information for precision spraying. Results demonstrated increased efficiency with competitive accuracy [24].

Development of proximal imaging systems with sensors close to objects for estimation of plant morphology and physiological processes, mountedon autonomous vehicles, helpsto identifysite-specific additional weed management approaches. Preciseweed monitoring needs measuring Leaf Area Index (LAI) and above the ground dry matter biomass. Such an approach may open up fresh perspectives of crop growth and weed monitoring with proximal sensing technologies [25].

Satellite-based remote sensing detects and maps weed presence through broadband multispectral sensors like VNIR (Visible and Near Infrared) of the electromagnetic spectrum and Atmospheric Resistance Vegetation Index (ARVI) as key variables [26].

Improvement in weed management over traditional methods transformed with advancement of IoT using remote-controlled robotic vehicles, low power and low-cost wireless sensors, notification on smartphone applications to engage farmers using Wi-Fi, 3G, 4G/LTE [27].Thus,the handy use of mobile phones is an essential communication tool empowering farmers with appropriate information in weed management and improveimplementation scopes further and broader reach to end-users [28]. Institutional roles are necessary for knowledge dissemination through such devices.

Challenges

India is estimated to have nearly 17% of the world's population. In 2019, the population in India ranked second in the world next to China (Table 3). An increasing population (Table 4) andever-increasing urbanizations require increased agricultural production as the focus of all farmers.

Table 3: World Population Ranking – 2019

Rank	Country	Population (2019)
1	People's Republic of China	1,396,530,000
2	India	1,254,020,000
3	United States of America	328,016,242
4	Indonesia	267,871,000
5	Pakistan	216,565,318
6	Brazil	208,495,000
7	Nigeria	200,963,599
8	Bangladesh	163,046,161
9	Russia	146,675,000
10	Japan	126,443,000

Weed control is an optimizing operational factor to enhance the yield. The challenge stretched further to emphasize food grain self-sufficiency and avoid food security.Applications of herbicides haveinherent ecological challenges.It's important to share such information to the farmers at the grass-root level on best agricultural practices and demonstrate improved weed control technologies for the precision use of herbicides. Thus, intrusive researches in the agriculture field are required to cover the issues under discussion.

Table 4: Population Growth Rate (%) - 2019

Country	Population Growth Rate (%) 2019
India	1.02%
United Kingdom	0.56%
Germany	0.27%
Canada	1.42%
People's Republic of China	0.36%
United States of America	0.47%

Combinatorial use of hybrid herbicides deployed by using precision tools is some improvisations or extended practices to reduce impacts of weed control on ecology. However, such technical fixes or improvements are yet to align and address the vulnerability of herbicide-resistant weeds, environmental impacts, and public health concerns.Dynamism in the simultaneous growth of weed and crops continues to be a critical factor in agricultural yield loss. Scientific understanding of weed biology and related competition with crops for an integrated implementation approach may help higher yield resolution.

In developing countries like India, many farmers use backpacks to spray herbicides for weed control.Such a manual process involves handhold sprayers and a manually operated compressed cylinder of liquid chemicals. This process induces uniform application of chemicals on visible weed areas with no scope to apply on specificcoverage regions.A precision spraying-weeders for optimal herbicide use can reduce herbicide consumptions by 80% and reducing cost in turn. Such improvement will minimize environmental risk and supplement economic farming. It's important to share such information with the farmers as best agricultural practices and demonstrate improved mechanisms to achieve it.

For more extensive cultivating lands, the use of robots in agriculture and robotic technology ease weed management. However,it has challenges related to crop types, the shape of the field, plant spacing, etc., that should consider before evaluating such options.For example, a robotic lawnmower (RLM) has a better working performance when compared with a riding mower (RM) and a walking mower (WM) in an orchard [29]. The challenge is to deploy efficient methodologies catering to simultaneous environmental beneficiary and site-specific weed control.

Precision tools with robotics and image processing in weed control are not available with easy affordability for sustainable solutions in many places, including India. The majority of farmers with smaller land areas depend on available cost-effective tools with low efficient conventional processes. Moreover, these tools do not address ecological and related harms, though they try to minimize them.

Industry involvement to device advanced sensor technology in precision weed control at an affordable cost is a challenge. There will be hurdles in farmer awareness for the safe and convenient use of such advanced devices.

Predicting crop yield with weed factor will continue to be a tricky proposition though wider acceptance and deployment of technical development can ease it further.

Way Forward For Futuristic Scope

The use of modern technology in weed control helped save the crops and improve the overall production rate. The role of advanced technology in increasing production rate is recorded or observed. It reflects that using advanced instruments or devices for herbicide applications in agriculture may provide a good future scope in enhancing crop production rates.Combinatorial use of herbicides using precision tools improves existing practices to reduce impacts of weed control on ecology (resistance, ecology, health, etc.).Systems-level ecological thinking can help appropriate agronomical decisions to achieve sustainable weed management.

We have witnessed consistent growth and high crop yields from the green revolution period. However, due to the steep increase in population, the agricultural production rate may not always match society's needs.Agood number of risks and challenges are still associated with weed control, as discussed. To over such challenges, researchers are working in multiple directions. Weed characteristics differentiating from crops are intensifying. Researchers can address the impactsof herbicide residues, herbicide-resistant weeds, the resultsofglobal climate change on crop-weed interaction, and environmental safety. With awareness of higher efficiency in weed control, herbicide consumption is on the rise. Dissemination of information to end-users to create awareness of ecological pressureis crucial. Impactsdemonstrated to minimize herbicidal residues by local organizations through academic and research institutions in collaboration with local administrations (panchayat, etc.) will directly connect to end-users (the farmers). A balance between technological advances and catering to the benefits through appropriate tool deployment among ordinary farmers is essential.It's time to support entrepreneurial efforts in developing various applications and technical instruments for weed control using advanced wireless sensors targeted at small farmers and providing services to them. The approach may open a vista for new agricultural entrepreneurship in rural development. These discussions suggest that a proper application of weed control technology can improve the required growth rate of agricultural production over time which willsignificantly enhance the level of society.

CONCLUSION

Literature reports the harmful impacts of weeds on agricultural growth. It also highlighted the role of technology in overcoming the various challenges caused by weed in the agro-economy and crop production. In view of this, the proposed review article discusses crop production and its salient features, constrained by natural factors (weather & climate) andfactors like weeds, diseases, pests, rodents, etc.

The thrust of the review is to highlight the various parameters that influence the crop production cultivating land ratio.The agricultural yield factor isa measure of the percentage of crop produced and associated enabling land area. While weather and climate are beyond human control, there is an utmost need to control weedsthrough improvisations in weed control processes and related applicable devices. A better grip over the issues requires a good understanding of weed characteristics in controlling the spread and separating it from the desired crop through appropriate processes. It can conceptually prevent weeds from growing or spreadingthrough cultural, physical, biological, and chemical methods.

For decades, among all the weed control practices, the chemical method is the most successfully practiced using various herbicides. Such weed control approaches have few shortcomings that need technological improvements to influence the overall crop production with maximum utilization of green and salty land as an agricultural field.Developments in precision technology and related alignment with agricultural applications aimat overcoming existingdrawbacks and challenges of prevailing weed control methods.

Agricultural growth impacted by weeds, associated challenges, and futuristic scopes highlighted in this review suggests that technologyplays a significant role in the agricultural growth rate to meet society's food security. It also provides an opportunity for a country to become self-sufficient in crop growth with available agricultural land.

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