India

Underweight *(no change)*

Highlighted Companies

PI Industries Ltd

REDUCE, TP Rs2872, Rs3742 close

PI Industries has done well, courtesy pyroxasulfone, but our analysis indicates that the medium-term growth of the company is at risk because of no big product in the pipeline. The new fungicide, dichlobentiazox, is still in a very early phase. Growth expectations are too high. Reiterate our REDUCE rating on the stock.

SRF Limited

REDUCE, TP Rs1540, Rs2518 close

The slowdown in the agrochemicals sector and headwinds on the HFC consumption front in the US are leading to sub-par export performance of SRF. As highlighted in this note, the terminal value of the agrochemical intermediate business is reducing, which is a further negative for SRF.

UPL Limited

ADD, TP Rs694, Rs485 close

At this time of the cycle, it's imperative to save balance sheet and vendor base. UPL is doing the right thing by not increasing receivables and saving its vendors. We value UPL at 20x FY26F P/E with a target price of Rs694.The potential listing of seed business will unlock germplasm repository value. Risk-reward 2:1, in our view, ADD.

Summary Valuation Metrics

P/E (x)	Mar24-F	Mar25-F	Mar26-F
PI Industries Ltd	44.5	40.88	37.44
SRF Limited	52.52	45.81	38.96
UPL Limited	-13.34	71.87	13.97

P/BV (x)	Mar24-F	Mar25-F	Mar26-F
PI Industries Ltd	6.75	5.82	5.82
SRF Limited	6.46	5.74	5.07
UPL Limited	1.33	1.27	1.14

Dividend Yield	Mar24-F	Mar25-F	Mar26-F
PI Industries Ltd	0.09%	0.09%	0.1%
SRF Limited	0.25%	0.25%	0.25%
UPL Limited	0%	0.37%	1.88%

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Chemicals - Overall

CRISPR reduces terminal value of agchems

- CRISPR technology is being widely adopted in plant genome editing and it is reducing the dependence on agrochemicals for pest/fungus management.
- The regulatory hurdles in adopting gene editing is slowly getting removed as gene editing is an accelerated mutation process and hence, it's not unnatural.
- Big agrochem/seed companies are frontrunners as this tech is restricted. It's cheaper to make such gene-edited seeds & unlike chemicals it can't be copied.

CRISPR is reducing the terminal value of agrochemical businesses

CRISPR technology and the resulting ease in which plant DNA can be manipulated to defeat fungus and insect attack opens a field for big seed companies. This technology cannot be replicated by copycats, which is easily done in the case of agrochemicals. Developing a gene-edited seed which won't have any competition from generics costs US$40-50m and four-to-five years whereas new agrochemical development can cost US$300 and take at least 10 years to develop. That's why most of the innovations in agrochemicals is happening in pre-emergent herbicides. Please remember post-emergent herbicides can only be used with herbicide-tolerant seeds and hence, in post- emergent herbicides, only big agrochemical companies are innovating. Japanese companies like Kumiai (who have no seed technology as such) are present in pre-emergent herbicides.

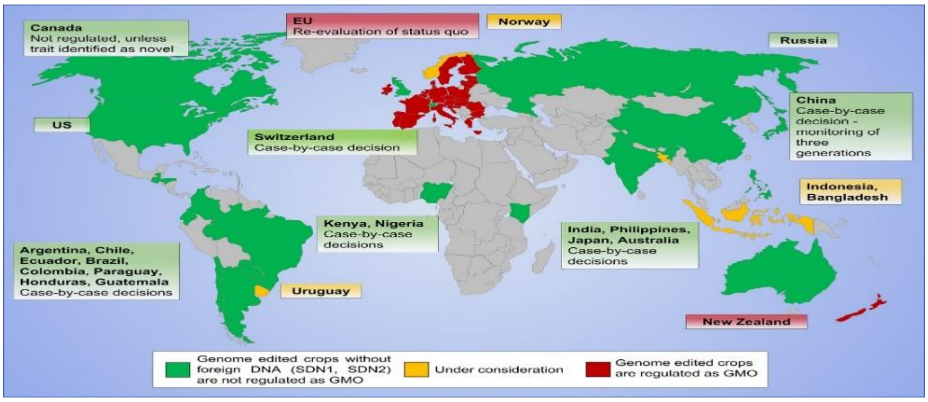
Most governments are treating gene-editing technology favourably

CRISPR is the tool for gene editing and most of the governments are looking at this technology favourably. Even India, which had a strict no-no position for GMO, is looking at gene-edited seeds favourably. Gene-edited seeds have wider implications: 1) Increasing agricultural yield, 2) reducing consumption of fertilizers, 3) replacing agrochemicals, primarily fungicides and insecticides. Sadly, as of now this technology is limited to a few like Dow, DuPont, Millipore Sigma, Cellectis, Toolmen Inc., Editas Medicine, CRISPR Therapeutics, ERS Genomics, and Casebia Therapeutics who hold patents acquired through research or licensing agreements. None of the Indian companies are even near to the prowess required for using CRISPR. May be germplasm repository of Indian seed companies can have some value in this regard and value unlocking is possible in UPL (ADD) and Rallis India (REDUCE).

Reduce exposure to agrochemicals and their intermediates

In the mad bull run in chemicals, every stock has run and hasn't fallen, despite earnings disappointment. Earnings expectations are too high. A good example is SRF whose EPS was projected to be Rs80+ at the beginning of FY24, but it will end at Rs42. But the stock is still at its FY22 peak. This is the story for all agrochemical companies as all such stocks will disappoint in FY25F as well. Remember SRF (REDUCE) and PI Industries (REDUCE), are all mainly agrochemical intermediate suppliers. One is better buying seed companies who have germplasm repository and the potential of value unlocking.

Figure 1: Gene-edited seeds have a favourable outlook even in India



SOURCE: INCRED RESEARCH, COMPANY REPORTS

CRISPR reduces terminal value of agrochemicals

Crispr technology, and the resulting ease in which plant DNA can be manipulated to defeat fungus and insect attack, opens a field for big agrochemicals companies. This technology cannot be replicated by copy cats, which is easily done in the case of agrochemicals. Developing a gene-edited seed which won't have any competition from generics costs US$40-50m and four-to-five years whereas new agrochemical development can cost US$300 and take at least 10 years to develop. That's why most of the new innovation is happening in herbicides (weeds still need to killed by using poison). Remember post-emergent herbicides can only be used with herbicide-tolerant seeds and hence, in post emergent herbicides, only big agrochemical companies are innovating. Japanese companies like Kumiai are only present in pre-emergent herbicides.

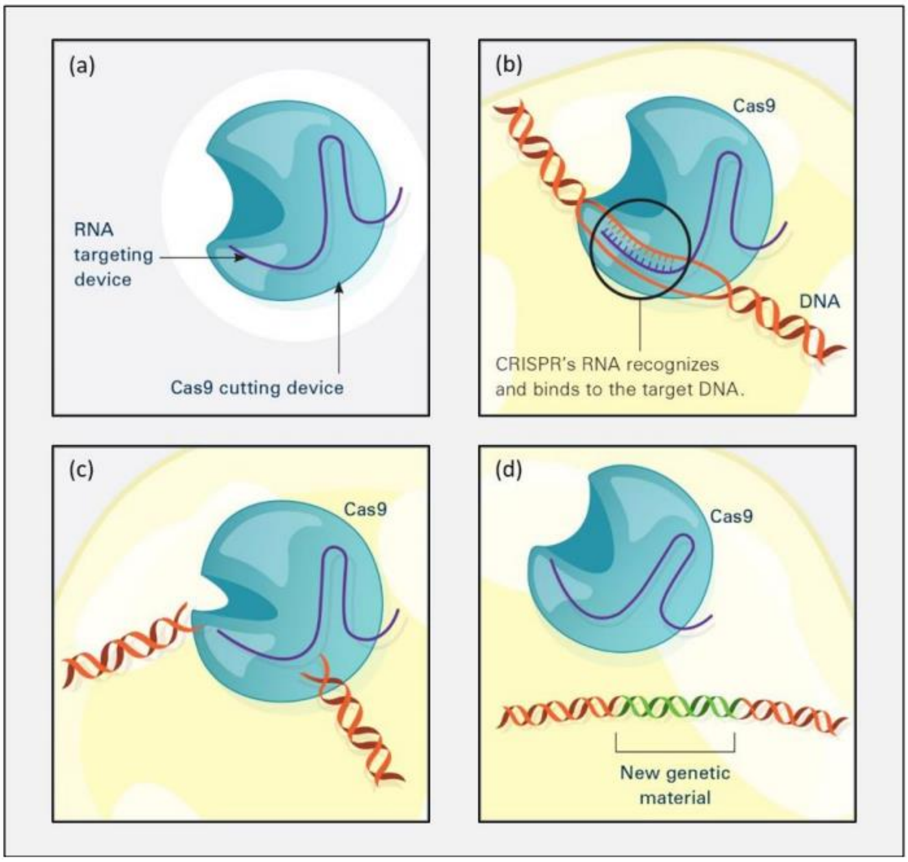
Basics of CRISPR technology

CRISPR stands for Clustered Regularly Interspaced Short Palindromic Repeats. It's a gene-editing tool inspired by a bacteria's immune system. Scientists discovered that bacteria use CRISPR as a part of their defence system against viruses. Bacteria capture snippets of viral DNA and store them in their own DNA. When a virus attacks again, the bacteria can recognize and destroy it using these snippets.

What is CRISPR?

1. CRISPR is biotechnology's most impactful development of this decade. It allows scientists to modify the DNA of plants and animals.
2. It is expected to affect all facades of life, from healthcare to agriculture. Owing to its huge impact, Jenniffer Doudna and Emmanuelle Charpentier were awarded the Nobel Prize in Chemistry for the development of the CRISPR-Cas9 system.
3. The CRISPR system is used to edit plant genome in the following manner:
   a. The CRISR system has two parts: an RNA sequence that targets the part of the DNA that will be edited and the CAS enzyme that cuts the DNA at the binding site.
   b. Once the CRISPR machinery is inside the cell, it identifies the target DNA.
   c. The Cas9 enzyme chops the target DNA.
   d. The new DNA is inserted into the place of chopped DNA.

Figure 2: The CRISPR machinery



SOURCE: INCRED RESEARCH, COMPANY REPORTS

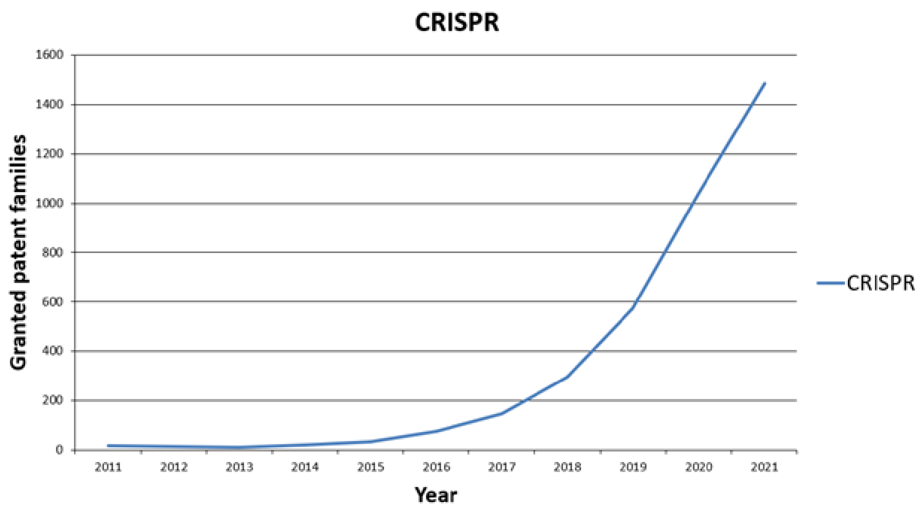
Big advantage: CRISPR crops can be classified non-GMOs

1. CRISPR targets the organism's pre-existing DNA for the introduction of desired traits. In contrast, traditional GM methods use external DNA.
2. CRISPR allows us to introduce natural genetic variations in the crop and not from organisms that are incompatible with crops reproductively.
3. This removes the underlying public fear that the plants and finished goods contain foreign DNA. Moreover, a few products that are developed using CRISPR will not be labelled as GMOs based upon the US Department of Agriculture or USDA regulations.

Patent landscape for CRISPR crops

1. Based on patent data, it is evident that the commercial use of CRISPR started around 2014-15 and it has gone up since then.
2. Figure 3 has a list of CRISPR patents for crops. The US is leading the list. This is followed by the UK and Canada. Europe has relatively fewer patents because of the strict regulatory landscape.
3. As observed in Figure 3, **global seed giants like Pioneer H-bred Int'l, Corteva Agrisciences, Syngenta, and Bayer are entering the field of developing CRISPR seeds.**
4. The patent filings in the pioneers from the field cover a wide range of plants like tomato, rice, tobacco, soybean, maize, wheat, rapeseed, alfalfa, cannabis, and cotton.
5. In terms of traits, there is a half and half mix between traits that are added to improve customer experience and traits that are added to assist the farmer. Reduction in the allergen level and browning, decrease in gluten, improvement in flavour, shelf life, and fruit colour are certain traits that are added to the plant via gene editing to improve customer experience. Resistance to viral, fungal, and bacterial agents, resistance to extreme temperatures and drought, and increased crop yield are the traits introduced via CRISPR that aid the farmers.
6. **A few examples of such products being commercially used are omega-3 fortified false-flax, browning-resistant mushroom, and high-amylopectin waxy corn.**

Figure 3: CRISPR patents granted from 2011-21



SOURCE: INCRED RESEARCH, COMPANY REPORTS

Figure 4: Patents for CRISPR crops

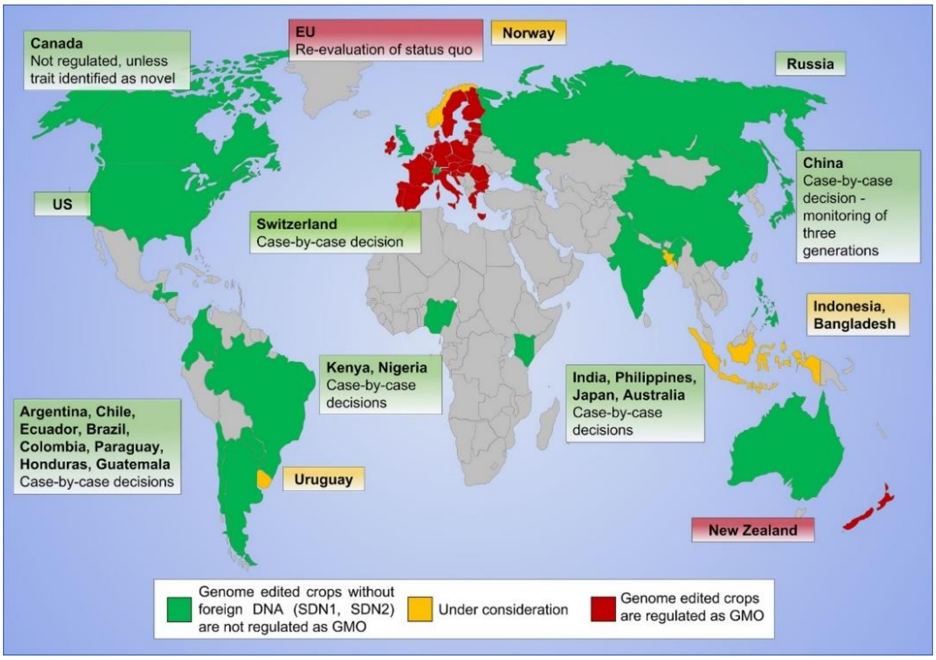
Company	Country	Plant
The Broad Institute	USA	Plants
Pioneer Hi-bred Int't	USA	Plants
Corteva Agriscience	USA	Plants
Syngenta	USA	Plants
Bayer	USA	Corn
Benson Hill Seaads Inc.	USA	Soybean
Indigo, Ag. Inc.	USA	Seeds, Soybean
Cellectis	France	Potato
China Agricultural University	China	Plants
Limagrain Cereal Seeds LLC	USA	Wheat
Sakat Seeds Americas Inc.	USA	Tomato, Polano Pepper
KWS SAAT SE + Co KGaA	Germany/USA	Plants
Pairwise Plant Services Inc	USA	Plants, Consumer Crops
Toolgen Inc.	USA	Potato
Carbou Biosciences	USA	Plants
Canbreed	Israel/USA	Cannabis
Nanjing Agricultural University	China	Plants
Arista Ceral Technologies	Australia	Wheat
Agrisoma Bioscience Inc.	Canada	Brassica Plant
Golden West Research	Bulgaria	Cotton
Ingari Agriculture	USA	Plant
King Abdullah University	Saudi Arabia	Tobacco
Nunhems B.V.	Netherlands	Cucumber, Carrot, Watermelon
Chinese Academy of Sciences	China	Plant
Central Valley Seeds Inc.	USA	Lettuce
Tropic Biosciences	UK	Banana
Cibus LLC	USA	Plant

SOURCES: INCRED RESEARCH, COMPANY REPORTS

Regulatory landscape of GE products

1. Regulatory frameworks categorize the three types of genome editing by site-directed nucleases (SDNs). SDN-1 introduces small changes at the target site. SDN-2 introduces specific DNA replacement in the genome via homologous recombination. SDN-3 introduces larger genetic elements like full genes.
2. There has been a public discourse over the past decade about whether non-transgenic edited plants are being treated the same as GMOs or whether the process used to generate the new plant lines should be considered and a separate regulatory framework should be applied to gene-edited crops. Different countries have drafted their guidelines taking different approaches around these two paths.
3. In the below discussion, we have summarized the global regulatory landscape for gene editing. European Court of Justice (ECJ) classifies all gene-edited plants as GMO whereas the US and several other countries classify gene-edited lines free of foreign DNA as traditional non-GMO plants. Russia, countries in Central and South America, and two countries in China have developed new policies in rapid succession to regulate gene-edited crops.

Figure 5: Current state of genome legislation (GMO, genetically modified organism; SDN, site-directed nuclease)



SOURCE: INCRED RESEARCH, COMPANY REPORTS

Policy for regulation of gene-edited crops in the US and UK

1. The Department of Agriculture (USDA), the Food and Drug Administration (FDA), and the Environmental Protection Agency (EPA) overlook the regulation of gene-edited (GE) crops in the US.
2. A guidance document was issued by the USDA in 2019. Based on it, **most of the gene-edited crops will not be facing the same regulatory scrutiny as conventional genetically modified organisms (GMOs).**
3. In the EU, GEs are required to undergo a tedious safety assessment process prior to approval. Overall, this process is costly and time-consuming due to which a lot of European countries are developing gene-edited crops. This can also be observed in Figure 3 where Europe has a fewer number of CRIPR patents compared to the US and Canada.

Policy for regulation of gene-edited crops in China ›

1. China regulated GEs under the same set of rules as GMOs until 2022. This was an arduous process that hampered innovation and commercialization.
2. Owing to the high dependence on imports of GM crops like soybean for cattle feed, the Ministry of Agriculture and Rural Affairs (MMRA) relaxed its regulations surrounding gene-edited crops and GMOS in Jan 2022, opening the doors for domestic options.
3. The following changes were made under the new guidelines:
   a. Separate guidelines for gene-edited crops: Based on this, there is a case-by-case approval process that is given on the grounds of the edits that are made and the risks that are associated with them.
   b. Streamlined approval: Gene-edited crops that do not have any foreign genes in them need less complex safety evaluation compared to GMOs.
   c. Pilot trial exemptions: Post successful pilot trials, gene-edited crops can apply for product certification without needing to conduct further field testing, thereby speeding up the commercialization.
4. The well-defined new regulations form a solid foundation for safe use of GM crops in China. Currently, GM cotton and GM papaya are grown on a large scale in China and have brought remarkable ecological and economic benefits. Furthermore, 12 corn events, 3 soybean events, and 2 rice events have also received biosafety certification, but these are yet to be commercially produced. In addition to these, six GM crops with 64 events, namely, soybean, corn, canola, cotton, papaya, and sugar beet have been approved as processing material in China.

Figure 6: Genetically modified plant events approved for commercial planting in China

Crop	Event name	Commercial trait
Cotton	GK12	Insect resistance
Cotton	Jinmian 26	Insect resistance
Cotton	NC33B	Insect resistance
Cotton	SGK-321	Herbicide tolerance
Cotton	DR409	Herbicide tolerance
Papaya	Huanong No. 1	Disease resistance
Papaya	YK-1601	Disease resistance
Corn	BVLA430101	Modified product quality
Corn	DBN9936	Herbicide tolerance + insect resistance
Corn	Ruifeng125	Herbicide tolerance + insect resistance
Corn	DBN9858	Herbicide tolerance
Corn	DBN9501	Herbicide tolerance + insect resistance
Corn	ND207	Insect resistance
Corn	Zheda Ruifeng 8	Insect resistance
Corn	DBN3601T	Herbicide tolerance + insect resistance
Corn	nCX-1	Herbicide tolerance
Corn	Bt11 x GA21	Herbicide tolerance + insect resistance
Corn	Bt11 x MIR162 x GA21	Herbicide tolerance + insect resistance
Corn	GA21	Herbicide tolerance
Soybean	SHZD3201	Herbicide tolerance
Soybean	Zhonghuang6106	Herbicide tolerance
Soybean	DBN9004	Herbicide tolerance
Rice	Huahui-1	Insect resistance
Rice	BT Shanyou 63	Insect resistance

SOURCE: INCRED RESEARCH, COMPANY REPORTS

Policy for regulation of gene-edited crops in India ›

1. India's policy for governance of gene-edited crops is currently undergoing changes and is building towards a more streamlined approach.
2. Before 2022, all genetically modified (GM) crops that were generated using traditional methods and CRISPR were regulated under the set of rules that fall under the Rules for the Manufacture, Use, Import, Export and Storage of Hazardous Microorganisms, Genetically Engineered Organisms or Cells, 1989. Owing to this, the approval process for all the GM crops was lengthy, including gene-edited crops.
3. In 2022, the Ministry of Environment, Forest, and Climate Change (MoEFCC) made a revolutionary decision by exempting certain categories of gene-edited crops from the regular lengthy approval process.
4. This exemption is applicable to two types of crops, namely:

   a. SDN-1: Crops where gene-editing is used to make changes to the crops' native DNA and no foreign DNA is introduced.
   b. SDN-2: Minute changes are made to the plant's native DNA using a molecular tool, but they are not permanent changes.
5. As both SDN-1 and SDN-2 categories do insert foreign DNA in the plant, they are low-risk, thereby eliminating the concerns raised by the old regulations.
6. Under the new relaxed regulations, SDN-1 and SDN-2 crops can undergo field trials and receive approval for commercialization in a faster timeframe.
7. Crops that have a foreign gene in them fall into the SDN-3 category and must undergo the conventional regulation process.

Commercially-approved CRISPR crops

1. GM High-Oleic Soybean, Calyxt, US
   a. Calyxt, an US plant-based synthetic biology company, has commercialized a gene-edited high oleic soy (free of trans fats).
   b. The high-oleic acid content eliminates the need for hydrogenation, a process that improves heat stability and shelf life of conventional soybean oil. The hydrogenation process contributes to production of trans-fatty acids, which raise cholesterol levels and contribute to contribute to cardiovascular diseases.
2. GM Herbicide Tolerant Canola, Cibus, North America Calyxt
   a. Cibus's herbicide-tolerant was the first gene-edited crop sold in the US and Canada.
   b. There are two Cibus canola varieties in Canada that are sold in Manitoba and Saskatchewan. It was launched in the US in 2016 and in Canda in 2018.
3. GM High-GABA Tomato, Sanatach Seeds, Japan
   a. This is the world's first genome-edited tomato for direct consumption.
   b. This tomato is created via the CRISPR-Cas9, and it has a higher level of gamma-aminobutyric acid (GABA). GABA is an amino acid that promotes relaxation and helps lower blood pressure.
4. GM Waxy Corn, Corteva, North America and Latin America
   a. Corteva Agriscience has received approval for GM waxy corn, a gene-edited crop produced via CRISPR-Cas9, in the US, Canda, Argentina, Brazil, and Chile. It has also received approval from Japan.
   b. Corteva used CRISPR-Cas9 to delete the waxy gene (Wx1) in corn, thereby increasing the proportion of amylopectin in starch to nearly 100%. In contrast, traditional corn starch has 75% amylopectin and 25% pectin.
   c. In addition to the food industry, amylopectin is also used in paper and textile industries.

CRISPR crops under development

1. Disease-resistant crops
   a. Phytopathogens are a leading cause of plant disease and are a global threat to agricultural production and safety of agro-based products. Approximately, 20-40% of losses in global agricultural production are due to plant diseases caused by phytopathogenic bacteria, fungi, nematodes, invertebrate pests, viruses, and weeds.
   b. Till date, a number of techniques like transgenic and tradional breeding have been employed for combatting crop diseases, but they are labourious, ineffective, and time-consuming.
   c. There is an effective and suitable alternative genome-editing solution available for development of disease resistant crops with the advent of

CRISPR. CRISPR also facilitates the development of transgene-free non-genetically modified plants, which are similar to the plants altered via transgenic or conventional breeding methods.

d. Several disease-resistant crops have been developed via gene-editing till date. These crops will have a greater public acceptance than the ones that are generated via the conventional gene modification process. Due to the above-mentioned reasons, we strongly believe that genome editing will make several significant contributions to crop productivity, thereby benefiting both the producers and consumers.

Figure 7: Application of CRISPR-Cas9 for the improvement of disease-resistant traits in crop species

Crop Species	Target genes	Result/trait improvement
Manihot esculenta	*MenCBP-1/2*	Cassava brown streak virus resistance
Hordeum vulgare	*HvMorc1*	*Blumeria graminis/Fusarium graminearum* resistance
Gossypium hirsutum	*Gh14-3-3d*	Verticillium dahlia resistance
Nicotiana benthamiana	*IR, C1*	Cotton leaf curl multan virus resistance
Brassica napus	*BnCRT1a*	*Verticillium longisporum* resistance
Triticum aestivum	*TaNFXL1*	*Fusarium graminearum* resistance
Citrullus lanatus	*Clpsk1*	*Fusarium oxysporum* resistance
Oryza sativa	*OsCul3a*	*Xanthomonas oryzae/Magnaporthe oryzae* resistance
Oryza sativa	*SWEET11, SWEET13* and *SWEET14/promoter*	*Xanthomonas oryzae* pv. *Oryzae* resistance
Citrus	*Citrus CsLOB1*	*Xanthomonas citri* subsp. *Citri* resistance
Cucumis sativus	*elf4E/cds*	Resistance to CVYV, ZYMV, and PRSMV
Glycine max	*GmF3H1/2, FNSII-1*	Soybean mosaic virus
Musa spp.	*ORF1, 2, 3* and *IR of BSV*	Resistance against Banana streak virus
Arabidopsis thaliana	*eIF4E*	Transgene free resistant against Clover yellow vein virus
Citrullus lanatus	*Clpsk1*	Resistance to *Fusarium oxysporum f.* sp. *niveum*
Capsicum annuum	*CaERF28*	Anthracnose disease resistance

SOURCE: INCRED RESEARCH, COMPANY REPORTS

2. Drought and salinity-resistant crops
   a. Abiotic stresses like salinity and drought impact food availability significantly.
   b. Conventional breeding techniques have been used to select plants that are more resistant to these stresses, but it is a time-consuming and laborious process. CRISPR can allow us to make genetic changes in plants that make them more tolerant to these stresses in a faster and effective way.
   c. Several crops are being developed using CRISPR to confer abiotic tolerance to crops.

Figure 8: Application of CRISPR-Cas9 for the improvement of abiotic tolerance in crop species

Crop Species	Target genes	Result/Trait improvement
Arabidopsis	OPEN STOMATA 2 (OST2)	Drought stress tolerance
Arabidopsis	miR169a	Drought stress tolerance
Maize	AUXIN-REGULATED GENE INVOLVED IN ORGAN SIZE 8 (ARGOS8)	Drought stress tolerance
Arabidopsis	Arabidopsis thaliana vacuolar H+- pyrophosphatase (AVP1)	Drought stress tolerance
Arabidopsis	ABA-responsive element- binding protein 1 (AREB1)	Drought stress tolerance
Rice	Rice type-B response regulator (OsRR22)	Salinity tolerance

SOURCE: INCRED RESEARCH, COMPANY REPORTS

3. Nutrient-enhanced crops:
   a. Malnutrition is rapidly increasing and is becoming a grave problem. According to estimates, 800m people are afflicted by malnutrition globally. Individuals, communities, and countries that undergo malnutrition suffer from long-lasting social, economic, developmental, and medical burdens.
   b. Biotechnology has been used to introduce biofortification in multiple crops to combat malnutrition. However, these methods are not feasible and have multiple limitations that can be addressed via the CRISPR-Cas system.
   c. The CRISPR-Cas system is being used to biofortify cereal crops like rice, barley, maize, and wheat, and vegetable crops like potato and tomato. It is also being used for qualitative improvement in shelf life, aroma, sweetness, and quantitative enhancements in protein, gamma-aminobutyric acid (GABA), protein, starch, anthocyanin, oleic acid, steroidal glycoalkaloid contents, and gluten.

Figure 9: Application of CRISPR-Cas9 for improvement of quality in crop species

Crop Species	Target genes	Result/trait improvement
Soybean	FAD2-1A and FAD2-1B	High oleic acid and low linoleic acid content
Grape	IdnDH	Decreased tartaric acid content
Rice	GW2, GW5, and TGW6	More grain length and width
Rice	Starch branching enzyme (SBEI) and SBEIIb	High-amylose rice
Tomato	ALC	Long shelf-life
Tomato	SlGAD2 and SlGAD3	Increase GABA content in tomatoes
Rice	Fatty acid desaturase (OsFAD2-1)	High oleic/low linoleic in rice bran oil
Rice	GS9	Round grains
Wheat	α-gliadin genes	Low-gluten meals
Wheat	TaGW2	Increases grain size and weight
Barley	GBSS1 and protein targeting to Starch 1 (PTST1)	Starch-free barley
Potato	steroid 16α-hydroxylase (St16DOX	Reduces the steroidal glycoalkaloids (SGA)
Tomato	OVATE, Fas, Fw2.2, and CLV3	Better yield and productivity in tomato crop lines
Tomato	SGR1, LCY-E, Blc, LCY-B1, and LCY-B2	Higher lycopene content
Sorghum	k1C gene family	Increased digestibility and protein quality
Carrot	F3H	Decreased anthocyanin acid content
Rapeseed	FAD2	Increased oleic acid content and decreased linoleic and linolenic acid contents
Cassava	GBSSI	Decreased amylose contents
Lettuce	LsGGP2	Increased n ascorbate content
Rice	(Phospholipase D) OsPLDα1	Reduced phytic acid content
Maize	(Shrunken-2 gene) SH2, and WX	Generation of sweet corn and waxy corn
Potato	StGBSS	Decreased amylase content
Tomato	PL, PG2a, and TBG4	Increasing the shelf life
Tomato	HYS	Decreased anthocyanin content
Peanut	FAD2A and FAD2B	Increased oleic acid content
Rice	OsBADH2	Introduction of aroma into an elite non-aromatic rice variety
Rice	OsGAD3	Higher gamma-aminobutyric acid (GABA) content
Maize	waxy gene	Fine-tuning amylase content
Potato	Polyphenol Oxidases (stPPO2)	Reduced browning
Tomato	SlDDB1, SlDET1, SlCYC-B	Increased carotenoid, lycopene, and β carotene
Tomato	FLORAL4	Increased phenylalanine-derived volatile content
Tomato	EXCESSIVE NUMBER OF FLORAL ORGANS (ENO)	Plants that yield larger multilocular fruits
Soybean	Gly mBd 28 K and Glym Bd30 K	Hypoallergenic soybean plants
Eggplant	PP04, PPOS, and PP06	Decreased browning
Brassica rapa	BrOG1A and BrOG1B	Decreased fructose and glucose and increased sucrose contents
Rapeseed	SFAR4 and SEARS	Increased oleic acid content and decreased linoleic and linolenic acid contents
Rapeseed	BnITPK	Decreased phytic acid content
Maize	CLE genes	Increase the yield
Maize	ZmBADH2a and ZmBADH2b	Popcorn-like scent
Potato	Starch branching enzyme (Sbe)	Increased amylose ratio and long amylopectin chains
Camelina	CsFAD2	Increased oleic acid contents
Banana	MaACO1	Increased shelf life

SOURCE: INCRED RESEARCH, COMPANY REPORTS

Impact on agrichemicals business

- Since its discovery in 2010, CRISPR has changed the face of drug discovery. CRISPR-Cas9 is the cue to new therapies for sickle cell anemia, hereditary blindness, and various cancers. Just like medicine, CRIPSR is set to revolutionize the field of agriculture soon. Newer crops like GABA tomatoes and waxy corn have hit the market and more crops like non-browning mushrooms and tomatoes with higher vitamin D will hit the shelves soon.
- A major incentive for CRISR is that it does not introduce genes from other organisms such as bacteria. Owing to this, countries such as the US, China, and India are opening their doors to CRISPR-edited crops and have deregulated them.
- As CRISPR changes the face of agriculture, a major segment that will be affected by it is agrochemicals. We have discussed the three categories of crops that will be developed via CRISPR: disease-resistant crops, nutrient-enhanced crops, and drought and salinity-resistant crops. Among these categories, disease-resistant crops are the ones that will affect agrochemicals the most. With the introduction of traits such as pest resistance within the crop itself, the use of agrochemicals such as pesticides will be trimmed.

Seeds are being developed which are resistant to various fungus attacks ➤

Gene-edited seeds with resistance to various fungus are still under development, but research is ongoing to create crops that can resist a wider range of fungal diseases. This is a promising area of agricultural biotechnology that has the potential to reduce reliance on fungicides, improve crop yields, and ensure a more sustainable food supply.

Here are some examples of fungal diseases that gene-editing is targeting:

Powdery mildew: This fungal disease affects many plants, including grapes, strawberries, tomatoes, and cucurbits (melons, cucumbers, squash). It appears as white powdery spots on leaves and fruits, reducing plant growth and yield. Researchers have successfully edited genes in tomatoes and cucumbers to make them resistant to powdery mildew.

Rusts: Rusts are a group of fungal diseases that attack many crops, including wheat, corn, soybean and coffee. They cause orange, brown, or yellow pustules on leaves and stems, which can significantly reduce crop yields. Scientists are developing gene-edited wheat varieties resistant to specific rust fungi.

Blights: Blights are fungal diseases that cause rapid wilting and death of plant tissues. They can affect a wide range of crops, including potatoes, tomatoes, and rice. Researchers are working on developing gene-edited potato varieties resistant to late blight, a devastating disease that caused the Irish Potato Famine in the 1840s.

The development of gene-edited seeds with fungal resistance is still in its early stages, but it has the potential to revolutionize agriculture. These seeds could help to reduce crop losses, improve food security, and make agriculture more sustainable.

InCred Equities

Some examples such as fungus-resistant seeds are given below

There are various examples of the seeds which are immune to fungus attacks. The case for ornamental plant is given below.

Figure 10: The example of ornamental plants shows how gene-editing progressed in leaps and bounds to curb fungus attacks

Recent advances in the genetic engineering of various ornamental crops for fungal disease resistance.

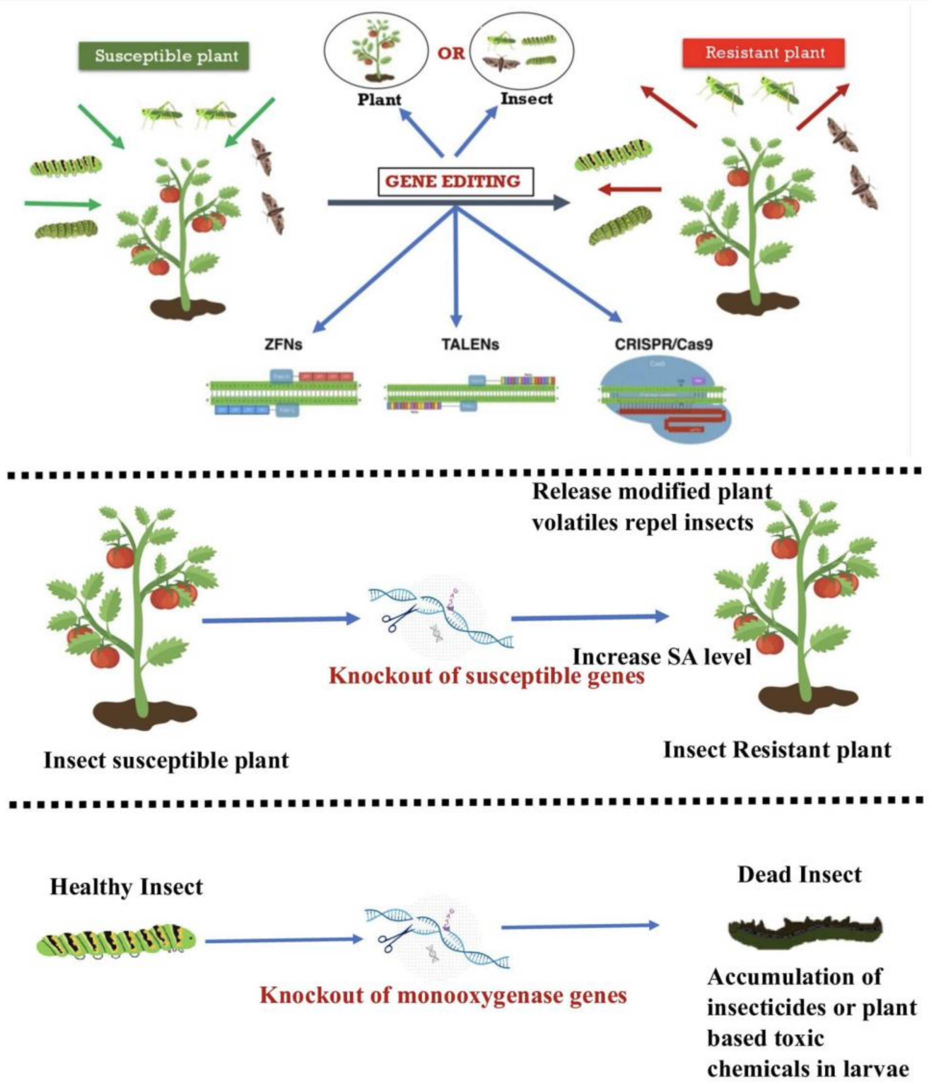
Crop	Gene	Disease Resistance
Rose (*Rosa hybrida*)	*Ace-AMP1*	powdery mildew (*Podosphaera pannosa*)
	rice *chitinase*	powdery mildew (*P. pannosa*)
	RhMLO1, RgMLO6, RlMLO7	powdery mildew (*P. pannosa*)
	rice *chitinase*	black spot (*Diplocarpon rosae*)
	chitinases, glucanases, and *RIPs*	black spot (*D. rosae*)
	Rdr1	black spot (*D. rosae*)
Chrysanthemum (*Chrysanthemum morifolium*)	*PGIP*	Alternaria leaf spot (*Septoria chrysanthemi*)
	hairpinXoo	leaf spot (*Alternaria tenuissima*)
	chiII	leaf spot (*Septoria obesa*)
	RCC2	gray mold (*B. cinerea*)
	CaXMT1, CaMXMT1, CaDXMT1	gray mold (*B. cinerea*)
	Cry1Ab and *sarcotoxin IA*	white rust (*P. horiana*)
	CmWRKY15-1	white rust
Petunia (*Petunia hybrida*)	*endochitinase* and *osmotin*	gray mold (*B. cinerea*)
	WD (Wasabi defensin)	gray mold (*B. cinerea*)
	NIC (Nakamura Ikuo Chitinase)	gray mold (*B. cinerea*)
Lily (*Lilium*)	*RCH10 chitinase*	gray mold (*B. cinerea*)
	Ire-miR159	gray mold (*B. elliptica*)
Carnation (*Dianthus caryophyllus*)	*PR-1, osmotin, chitinase*	Fusarium wilt (*F. oxysporum*)
	bacterial *chitinase*	Fusarium wilt (*F. oxysporum*)
	jasmonate methyl transferase	Fusarium wilt (*F. oxysporum*)
Gladioulus (*Gladiolus communis*)	*D4E1*	Fusarium wilt (*F.oxysporum*)
	Fungal *exochitinase, endochitinase*, bacterial *chloroperoxidase*	Fusarium wilt (*F. oxysporum*)
Geranium	*Ace-AMP1*	gray mold

SOURCES: COMPANY REPORTS, INCRED RESEARCH

Much more material on gene-edited seeds and its usage can be found on Cornell University website www.cornell.edu

The technology and landscape for gene-edited insect resistance of plants is mostly ready

Figure 11: The basic framework for insect-resistant gene-edited plant is ready and it's a matter of time before it gets much adoption



SOURCES: COMPANY REPORTS, INCRED RESEARCH

Some examples of gene-edited seeds which can ward off threats of fungus and pests and thus negatively impact the sales of agrochemicals

A few examples of pesticide sales affected by CRISPR-based resistance are as follows:

- Resistance to cotton curl leaf via CRISPR will curb the sales of imadocloprid and dinotefuran.
- Tomato's resistance to powdery mildew and tomato leaf curl virus will curb the sales of benzovindiflupyr, epoxiconazole, prothioconazole, and pyraclostrobin.
- Resistance of rice to:
  - Rice tungro disease will curb the use of acephate.
  - Rice blast disease will curb the use of azoxystrobin.

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