



Research Paper

## Herbicides from nature-Opportunities for new target site discoveries

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### ABSTRACT:

Weeds comprise a major cause of crop yield loss as high as 34% worldwide, a figure much higher than other pests. During the period 1950s to mid 1980s, a new mode of action was discovered every two years leading to newer and newer reports of herbicide discoveries. The major modes of action in herbicides were PSII photosynthetic inhibitors and cell division (mitosis) inhibitors. Interest of agrochemical industry in new weedcidal molecules declined in mid 1990s due to unviable hike incost of R& D projects, increased barriers raised by toxicological and environmental legislations and success of glyphosate resistant crops. Natural class of toxins offer novel chemical groups of pesticides like glufosinate, bialaphos which are environmentally benign and attack new molecular target sites like glutamine synthetase that are not being exploited by pesticides currently available in market for sale. New herbicide action sites are of considerable interest for the herbicide industry. There are more than 25 or so commercial herbicide target sites that are currently used and research with natural phototoxins has demonstrated several additional novel potential herbicide target sites. Structural diversity and developed biological activity of natural phytotoxins now give opportunities for production of directly used natural compounds and synthetic herbicides with new molecular target sites, which can serve as the cornerstone of conventional herbicide discovery efforts. Extensive R&D aimed at the weed metabolism based design of molecules and products can serve as way forward in the discovery of herbicides.

**KEYWORDS:** Weeds, natural products, enzymes, target sites, resistance development, herbicide discovery

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### I. INTRODUCTION:

Weeds are the most severe and wide biological constraint to crop production and cause invisible damage till the crop is harvested (Vissoh et al., 2004). Weeds compete with crops for water, nutrients and light and they are of considerable concern to farmers (Radhakrishnan, 2018). Weeds reduce agricultural production, displaces native species and contributes dramatically to land and water deterioration (Rana and Rana, 2016). Weeds contribute as high as 34 percent of the total losses caused by agricultural pests (Oerke, 2006). Manual weeding, mechanical, cultural, chemical and biological methods are often used as different weed management strategies (Hatcher and Melander, 2003). Herbicide dependence has grown over time due to convenience in application and rapid response (Sparks, 2012) but their prolonged use results in numerous health risks for humans and animals, persistence of soil herbicides, contamination of water bodies, residue accumulation in plants and soil (Altman et al., 1990) and resistance that has become a major concern in controlling weeds (Jussaume and Ervin, 2016). As an example, in 2020, 262 species (152 dicots + 110 monocots) of weeds became herbicide resistant and 23 of the 26 known herbicide action sites are found to be resistant. Weed resistant to herbicides has been reported in 92 crops in 70 countries ([www.weedscience.org](http://www.weedscience.org)). Herbicides with new modes of action are badly needed to manage the evolution of resistance of weeds to existing herbicides (Duke, 2012). The reasons for the paucity of number of new herbicide modes of action for more than two decades partially attributed to the high expense of manufacturing a single active ingredient from \$184 million (2000) to \$286 (2016); (Dayan, 2019), introduction of glyphosate resistant crops and the expenses of fulfilling regulatory criteria has also increased (Duke, 2012). Multinationals are projecting in this situation that there is urgent need to introduce new chemistry with new MOAs. This seems to be expressed in recent presentations at the 2019 International Union of Pure and Applied Chemistry (IUPAC) congress on plant protection in Ghent, Belgium and the division of the American Chemical Society's Agrochemical Division at its 2019 regional meeting in San Diego, CA (Dayan, 2019). New herbicides with safer toxicological and environmental profiles

and new mode of action are badly needed. Natural products with a high structural complexity have higher potential for the discovery of a new mode of action (Dayan,2014). Natural products (NPs) are small molecules of < 1500 Da primarily derived from microorganisms and plants (Yan et al.,2018). As several natural products of plant species were patented as herbicides, none of these were commercially developed but some of microbial products including glufosinate and bialophos have been commercialized (Duke & Lydon,1987 ).In all pesticide MOAs, about 6, 11 and 16 per cent of commercial MOAs were derived from natural products or compounds inspired by natural products for herbicides, insecticides and fungicides respectively (Duke and Dayan, 2015). Therefore, weed control has to be implemented in an environmentally sustainable, economical and effective way. Following natural compounds represents some new MOA with potential use as herbicides-

Plant process	Natural phytotoxin	Source	Reference
<b>Amino acid synthesis</b>			
Glutamine synthetase	Phosphinothricin Tabtoxinine-β-lactam Phaseolotoxin	Streptomyces spp. And Pseudomonas spp. Pseudomonas syringae pv. tabaci Pseudomonas syringae pv. Phaseolicola	Dayan and Duke ,2014 & Seto et al.,1982 Turner,1981 Moore et al.,1984
Ornithine carbamoyl transferase	5-methyl tryptophan	Cantharellus cibarius	Yanofsky and Crawford,1972
Trp synthase	Gostatin	Streptomyces sumatrensis NK-23	Murao et al.,1981
Aspartate transaminase	Cornexistin aspartic acid	Paecilomyces variotii Aspergillus terreus	Duke et al.,2002 Duke et al.,2019
Dihydroxy acid dehydratase			
<b>Lipids synthesis</b>			
β-Ketoacyl-ACP synthase	Thiolactomycin Cerulenin Cyperin	Nocardia and Streptomyces Cephalosporium cerulens Preussia fleischhaktii	Duke, 2011 Duke,2011; Dayan and Duke, 2014 Dayan et al.,2008
Enoyl-ACP reductase	AAL toxins and the	Alternaria alternata and Fusarium moniliforme	Mirocha et al.,1992
Ceramide synthesis	fumonisins		
<b>Membrane functions and lipid stability</b>			
H <sup>+</sup> ATPase	Sorgoleone	Sorghum bicolor	Rasmussen et al.,1992 (Hejl and Koster, 2004)
NADH Oxidase	Juglone Fusicoccin Glaucaurubolone	Juglans spp., Fusicoccum Amygdali Castela polyandra	Ballio et al.,1964) Dayan and Duke ,2014).
Membrane and cuticle destabilize	Syringomycin Beticola Cercosporin Sarmentine	Pseudomonas syringae Cercospora beticola Cercospora kikuchii Peper longum	Bender et al.,1999 & Gross et al.,1997  Goudet et al., 2002 Duke and Dayan,2014)Huang et al.,2015
<b>Energy transfer</b>			
Coupling factor 1 ATPase	Tentoxin	Alternaria alternate	Lax and Shepherd, 1988
Photophosphorylation uncoupler	Nigericin	Streptomyces hygroscopicus	Heisey and Putnam., 1986
Photosystem II	Sorgoleone fischerellin A Aurachin	Sorghum spp. Fischerella musciicola Stigmatella aurantiaca	Hoagland, SJ Cutler,2000Srivastava et al.,1998 Oettmeier et al.,1990 Gerwick et al.,1997
Photosystem I	Pyridazocidin	Streptomyces spp	
<b>Photosynthetic pigments</b>			
p- hydroxy phenyl pyruvate dioxygenase	Leptospermone Usnic acid Sorgoleone Cinnmethylin Fosmidomycin	Leptospermum scoparium Lichen spp. sorghum spp -	Romdhane et al.,2016 Dayan and Duke,2014 Dayan and Duke,2014 Jones, R.G., 1990 Parkinson,2019
Tyrosine Aminotransferase		Streptomyces lavendulae	
Deoxyxylulose -5-phosphate reductase			
<b>Gene expression and regulation</b>			
Peptide deformylase	Actinonin	Actinomycetes (MG848-hF6)	Hou and Williams, 2006
Serine/ threonine protein phosphatases	Cantharidin Hydantocidin	Epicauta spp. & Lytta vesicatoria Streptomyces hygroscopicus	Dayan,2019 Heimetal,1995
Aenylsuccinate synthetase			

**Table 1. showing some phytotoxins**

## 1. Amino acid synthesis

### 1.1 Glutamate synthetase

Glutamate synthetase, a key enzyme involved in amino acid synthesis is the target site of naturally occurring phosphinothricin (homoserine-4-yl-(methyl)phosphinate) that is produced by *Streptomyces* spp. and *Pseudomonas* spp. (Dayan and Duke, 2014). Phosphinothricin, a microbial toxin (Ahmad and Malloch, 1995) is a non-selective, foliarly used herbicide that inhibits glutamine synthetase and is considered to be environmentally benign (Krieg et al., 1990). Glufosinate is merely commercial herbicide with this MOA having phosphinothricin as an active ingredient and is irreversible inhibitor of glutamate synthetase (Manderscheid and Wild, 1986). It is sold globally under different trade names such as: Basta® (AgrEvo, Frankfurt am Main, Germany; Franco et al., 1996), Buster®, Challenge®, Finale®, Harvest®, and Ignite® (Hoerlein, 1994). Phosphinothricin is a broad-spectrum herbicide (Kang et al., 2019) and contact herbicide (Shelp et al., 1992). Phosphinothricin, as Glutamate synthetase inhibitor leads to ammonia accumulation and also lowers stomatal conductance after its application (Coetzer and Khatib, 2001). However, a new discernment on MOA by weed research laboratory at Colorado State University implies that glufosinate leads to extensive production of reactive oxygen species (ROS) that induces lipid peroxidation of the cell membranes and immediate death of cells (Dayan, 2019). Glufosinate shows more effectiveness than glyphosate on some weeds like morning glories (Culpepper et al., 2000). Glyphosate [*N*-(phosphonomethyl)glycine], a dominant broad-spectrum herbicide globally (Duke and Powles, 2008) is structurally similar to glufosinate, but has an entirely different site of action site (Dayan and Duke, 2014). At this time, there are no scientifically confirmed cases of evolved weed resistance to glufosinate.

Bialaphos or bilanophos, having novel tripeptide (1-alanyl-1-alanyl-phosphinothricin) as active ingredient derived from *Streptomyces hygroscopicus* (Seto et al., 1982) and *S. viridochromogens* also inhibits Glutamate synthetase (Thompson, 1987). It is a proherbicide, requiring metabolic conversion to phosphinothricin in the target plant for herbicidal activity (Duke et al., 2002). It is sold in Japan as minor herbicide and its Cost of production may be one of the reasons that bialaphos has a very small market (Duke et al., 2010).

Tabtoxinine- $\beta$ -lactam derived from *Pseudomonas syringae* pv *tabaci* which causes wildfire diseases in *Nicotiana tabacum* (Turner, 1981) and Phosalacine, analogue of bialaphos that is isolated from *Kitasatoporia phosalacinea* has L-leucine as the C-terminal instead of L-alanine (Hogland, 1988).

### 1.2 Orn carbamoyl transferase

Orn carbamoyl transferase is involved in urea cycle that converts ornithine and carbamoyl phosphate to citrulline. The product of ornithine transcarboxylase (OCTase) is citrulline, a precursor of arginine. Therefore, inhibition of this enzyme results in loss of arginine production (Duke and Dayan, 2011).

A microbial toxin, phaseolotoxin (sulfodiaminophosphinyl) derived from *Pseudomonas syringae* pv. *Phaseolicola* is responsible for halo blight in bean plant inactivates ornithine carbamoyltransferase (Moore et al., 1984) that converts ornithine and carbamoyl phosphate to citrulline. The product of ornithine transcarboxylase (OCTase) is citrulline, a precursor of arginine. So, inhibition of this enzyme results in loss of arginine production (Duke and Dayan, 2011). It has not been commercialized and is non-specific type of toxin (Ferguson et al., 1980).

### 1.3 Tryptophan synthase

A natural compound (5-methyl tryptophan) derived from *Cantharellus cibarius* inhibits tryptophan synthetase or L-serine hydrolyase (Yanofsky and Crawford, 1972) which catalyses last step of tryptophan synthesis (Dayan and Duke, 2014).

### 1.4 Aspartate transaminase

A novel inhibitor of aspartate aminotransferase inhibitor called gostatin (5-amino-2-carboxy-4-oxo-1, 4, 5, 6-tetrahydropyridine-3-acetic acid); (Murao et al., 1981) has been identified from *Streptomyces sumanensis* NK-23. Gostatin, the time dependent inhibitor of aspartate aminotransferase and alanine aminotransferase (Nishino, T. and Murao, S., 1983) (Nishino et al., 1984) is a type of suicide substrate (mechanism-based inhibitor) that modifies irreversibly both pyridoxal phosphate (PLP) and pyridoxamine phosphate (PMP) moieties of AST (Kitagish et al., 1988).

Cornexistin (C<sub>16</sub>H<sub>20</sub>O<sub>6</sub>) and hydrocornexistin are microbial products of a fungus *Paecilomyces variotii*. Both of these compounds are highly phytotoxic and have been patented as herbicides (Duke et al., 2002). Cornexitin listed as a postemergence herbicide used against young annual and perennial monocotyledonous and dicotyledonous plants (Nakajima, 1991) having activity greater than bialaphos and almost equal to glyphosate (Takahashi et al., 1994).

### 1.5 Dihydroxy acid dehydratase

Dihydroxy acid dehydratase (DHAD) is the last important enzyme of amino acid biosynthesis (Dayan...,2019) being the target site of phytotoxin aspterric acid derived from soil fungus *Aspergillus terreus* that is extracted by a research group at university of california Los Angles (Duke et al.,2019). Aspterric acid shows properties similar to post emergence herbicides and can serve as a potential developmental lead for broad spectrum herbicides ( Lei, 2018).

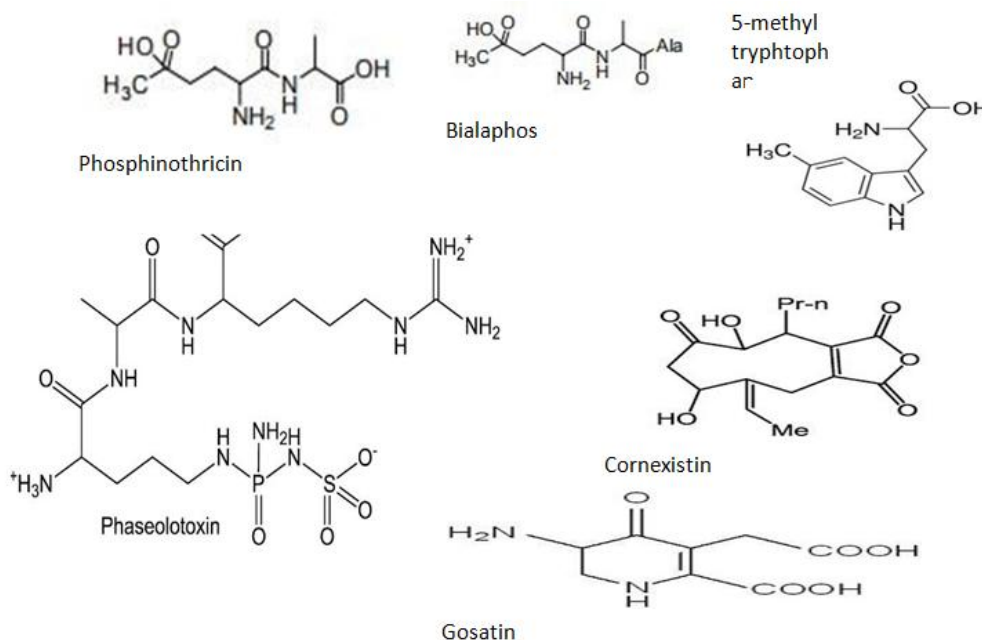


Fig- 1 Structures of some natural phytotoxins that target amino acid biosynthesis

## 2. Lipid synthesis

### 2.2 $\beta$ -Ketoacyl-ACP synthase

$\beta$ -Ketoacyl-acyl carrier protein synthase (ACP) is the key enzyme for biosynthesis of medium chain and long chain fatty acid (condensing enzymes, KAS) (Schütt et al., 2002). Thiolactomycin, a microbial product was obtained from unknown species of *Nocardia* and *Streptomyces* and is an effective fatty acid synthetase inhibitor of incorporation of acetate into chloroplast fatty acids ( Duke.,2011 ). Cerulenin, a natural fungal product derived from *Cephalosporium cerulens*, also inhibits fatty acid synthesis in plastids (Duke,2011); (Dayan and Duke.,2014).

### 2.3 Enoyl ACP reductase

Enoyl-[acyl-carrier-protein](ACP) reductase, a key enzyme that is involved in the last step of fatty acid synthesis (Heath et al.,2000). The diphenyl ether compound cyperin is a natural fungal phytotoxin obtained from *Preussia fleischhakei*, *Phoma sorghina*, and *Ascochyta cypericola* that inhibits ENR, which is also the target site of synthetic antimicrobial diphenyl ether Triclosan (Duke and Dayan.,2011). Therefore, cyperin destabilizes the membrane integrity of the cells. (Dayan et al.,2008) and it shows excellent herbicidal activity against *Cyperus rotundus*, *Arabidopsis thaliana* and *Agrostis palustris* ( Harrington et al., 1995 ).

### 2.4 Ceramide synthesis

A process called Ceramide synthesis involves biosynthesis of sphingolipid components of cell membranes that is catalysed by an enzyme Ceramide synthase (Abbas et al.,2002). The AAL toxins and the fumonisins produced by *Alternaria alternata* f.sp. *lycopersici* and *Fusarium moniliforme* respectively (Mirocha et al.,1992) inhibit ceramide synthase (Abbas et al.,1994). Research has been carried to improve ceramide synthase as a tool for effective herbicides (Abbas et al.,2002).

## 3. Membrane functions and lipid stability

### 3.1 $H^+$ ATPase

Sorgoleone (2-hydroxy-5-methoxy-[(8Z,11Z)-8,11,14-pentadecatriene]-p-benzoquinone); (Heji and Koster, 2004), a hydrophobic natural compound obtained from *Sorghum bicolor* (Rasmussen et al.,1992) acts as an  $H^+$  ATPase inhibitor. Sorgoleone's herbicide activity on many weeds (Besançon et al., 2020) makes it one of the most studied natural phytotoxins (Dayan et al., 2020). It controls different weeds such as *Galium spurium*, *Rumex japonicus*, *Aeschynomene indica* (Heji,2002). Sorgoleone shows more than one MOA,

which would minimize the development of target site resistance( Dayan and Duke ,2014)

Juglone, a quinone obtained from the roots of *Juglans* spp., reduces root H<sup>+</sup>-ATPase activity and caused reduced water uptake. Sorgoleone and juglone reported shows identical effects as both targets H<sup>+</sup> ATPase. (Hejl and Koster, 2004).

### **3.2 NADH Oxidase**

Fusicocin, a naturally occurring product derived from culture filtrates of *Fusicoccum Amygdali* (Ballio et al.,1964) leads to wilting due to inability of the plant to close stomata and Glaucarubolone obtained from root bark of *Castela polyandra* inhibits plasma membrane NADH oxidase. (Dayan and Duke ,2014).

### **3.3 Membrane and cuticle destabilize**

The plasma membrane is present at the interface between the cell and its environment. Destabilization of the plasma membrane has harmful effects on plants (Dayan and Duke, 2014).Syringomycin (lipodepsinonapeptide) derived from *Pseudomonas syringae* causes depolarization of plasma membrane which further causes rapid ion flux, eventually death of plant cell occurs (Bender et al.,1999);(Gross et al.,1997).

Another non peptidal fungal toxin beticola obtained from *Cercospora beticola* (causes leaf spot in sugarbeet) assembles into channel like structure which leads to electrolytic leakage and rapid cell death (Goudet et al., 2002). Cercosporin obtained from *Cercospora kikuchii* leads to peroxidation of membrane and thus, acts as a membrane destabilize(Duke and Dayan,2014) .

Sarmentine,a natural N-(2E,4E-Decadienoyl) pyrrolidine compound obtained from *Peper longum* has numerous attracting properties including its broad spectrum activity on several weeds as a contact herbicide (Huang et al.,2015).Sarmentine acts in same way as herbicidal soaps like pelargonic acid that acts as desiccants by stripping off the waxy cuticular layer from leaf surface .It shows multiple modes of action (Dayan et al.,2015) and studies reveal that it is more phytotoxic against *E.crusgalli* and *A. retroflexus* (Feng et al.,2019).

## **4. Energy transfer**

### **4.1 Coupling factor 1 ATPase**

Coupling factors plays a vital role in transferring energy from high energy state to ATP ( Dayan and Duke, 2014). Tentoxin, a cyclic tetrapeptide obtained from *Alternaria alternata* (Lax and Shepherd, 1988) inhibits CF1 ATPase in the chloroplasts ,a target site of no commercial herbicide(Dayan and Duke,2014). Tentoxin inhibits the release of a tightly bound molecule of ADP from CF1, which was caused by the binding of the ATP analogue adenylyl-beta,gamma-imidodiphosphate (AMP-PNP). AMP-PNP (Hu et al.,1993). Therefore, it is an energy transfer inhibitor which acts at final steps of ATPsynthesis(Arntzen,1972).Tentoxin has been patented as a herbicide and is both highly toxic in nature and selective, killing a variety of weeds at concentrations that have no effect on several crop plant s( Duke et al.,2010).

### **4.2 Photophosphorylation uncoupler**

Nigericin derived from wild strain of *Streptomyces hygroscopicus* (Heisey and Putnam., 1986) acts as a photophosphorylation uncoupler that enhances non-phosphorylating electron transport and thus reduces phosphorylation (Dayan and Duke ,2014).

### **4.3 Photosystem II**

Photosystem II is a pigment protein complex all oxygenic autotrophic organisms (Dayan and Duke, 2014). Sorgoleone, extracted from sorghum root exudates, is phytotoxic to narrow and broadleafweed species and acts through inactivation of photosynthetic electron transport (PS II) (RE Hoagland, SJ Cutler,2000).It is a powerful inhibitor of photosynthetic electron transport (Nimbal et al.,1996) and causes decline in oxygen evolution by thylakoid membranes (Rimando et al.,1998).

A microbial product ,fischerellin A (FS) produced by cyanobacterium, *Fischerella muscicola*, strongly inhibits the growth of photosynthetic organisms by targeting photosystem II (Srivastava et al ..,1998). It shows antifungal and herbicidal activity with Structural elements as enediyne moiety with two heterocyclic ring systems (Hagmann, L. and Jüttner, F., 1996).

The naturally occurring aurachin, a quinolone extracted from *Stigmatella aurantiaca* also shows inhibition of photosystem II and cytochrome b/c-complexes (Oettmeier et al.,1990).

### **4.4 Photosystem I**

Photosystem I is a membrane protein complex that uses light energy to transfer electrons from the luminal electron carriers plastocyanin or cytochrome c<sub>6</sub> through the photosynthetic membrane to the stromal electron carriers ferredoxin or flavodoxin (Dayan and Duke.,2014).Pyridazocidin produced by *Streptomyces* spp. Seems to be first naturally occurring compound that acts through reversible oxidation or reduction linked to PS I and it causes necrosis and chlorosis in weeds (Gerwick et al.,1997).

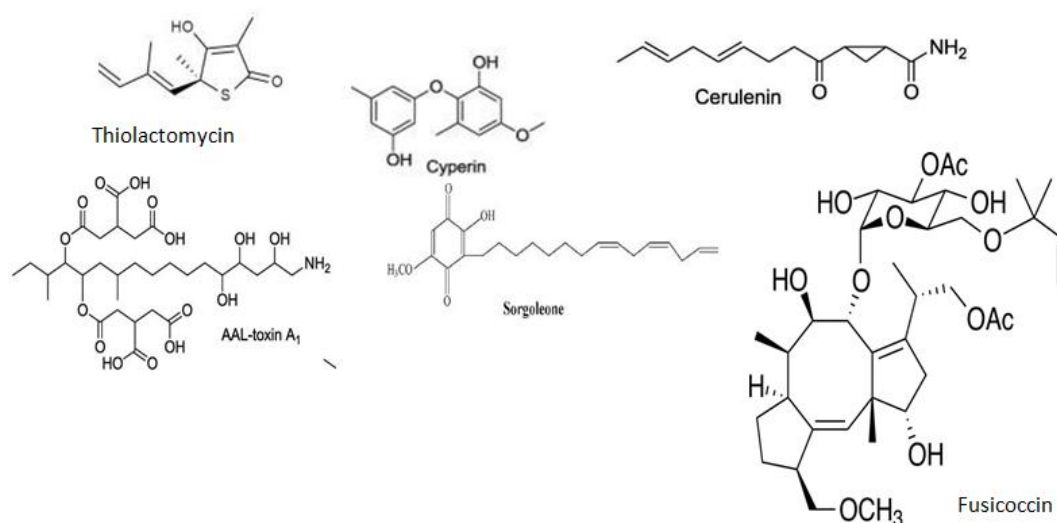


Fig 2. Structures of some natural compounds mentioned above in text.

## 5. Photosynthetic pigments

### 5.1 p- hydroxy phenyl pyruvate dioxygenase (HPPD)

p- hydroxy phenyl pyruvate dioxygenase (HPPD) is the key enzyme involved in the biosynthesis of prenyl quinones (Dayan, 2019) and tocopherols that is the target site of  $\beta$ -triketone, leptospermone [2,2,4,4-tetramethyl-6-(3-methyl-1-oxobutyl)-1,3,5-cyclohexanetrione], a natural compound obtained from essential oil of Manuka tree (*Leptospermum scoparium*); (Romdhane et al., 2016) and its components grandiflorone and flavesone are also powerful against HPPD (Dayan et al., 2007). The  $\beta$ -triketone herbicides have both preemergence and postemergence herbicidal activity, resulting in bleaching of treated plants and significant reduction in plant growth (Owens et al., 2013). Inhibition of HPPD was the last herbicide MOA developed for major commercial herbicides in past 25 years. There are some other naturally occurring compounds that can inhibit HPPD are Usnic acid obtained from lichens and Sorgoleone, an allelochemical produced by sorghum spp. (Dayan and Duke, 2014).

### 5.2 Tyrosine Aminotransferase

An enzyme named tyrosine aminotransferase converts tyrosine to 4-HPP in the prenylquinone pathway that provides plastoquinone, a cofactor of phytyl desaturase in carotenoid synthesis (Grossmann et al., 2012). Cinnemethylin, a 1,4 cineole derivative under trade name ARGOLD inhibits Tyr Aminotransferase that is a novel herbicide of the cineole class and it is developed as a herbicide for killing weeds in rice at lower doses (Jones, R.G., 1990) and it is a proherbicide (Hoagland, 2000).

### 5.3 Deoxyxylulose -5-phosphate reductase

Fosmidomycin, 3-[N-formyl-N-hydroxy amino] propyl phosphonic acid, (Possell et al., 2010) produced by *Streptomyces lavendulae* (Parkinson, 2019). Fosmidomycin, an antibiotic and herbicidal compound inhibits growth of several bacteria and plants, reveals that the DOXP pathway of isoprenoid biosynthesis is effectively blocked by fosmidomycin. Therefore, it acts as a probable target enzyme of fosmidomycin (Zeidler et al., 1998).

## 6. Gene expression and regulation

### 6.1 Peptide deformylase

Peptide deformylase is a key enzyme that inhibits protein translation in prokaryotes by removing the N-formyl group from N-formyl methionine (Dayan, 2019). Peptide deformylase, the target site of Actinonin, a hydroxamic acid derived from a soil actinomycetes (MG848-hF6) and it has been patented as a herbicide but not yet developed as a commercial herbicide. It causes stunting, bleaching, necrosis in different weeds (Dayan, 2019) and it shows both pre emergence and post emergence herbicidal activity (Hou and Williams, 2006).

### 6.2 Serine/ threonine protein phosphatases

Endothal, an old aged herbicide, and Cantharidin, a natural product obtained from the blister beetle (*Epicauta* spp.) and Spanish fly (*Lytta vesicatoria*) suppresses plant serine/threonine protein phosphatases (Dayan, 2019). Endothal, an older commercial herbicide product acts as slow, irreversible inhibitors of the serine/threonine protein phosphatase (Bajsa et al., 2012). Endothal is an effective herbicide to manage aquatic

weeds (Dayan ,2019).

### 6.3 Adenylosuccinate synthetase

Hydantocidin is a fermentation product derived from *Streptomyces hygroscopicus*. It is a powerful phytotoxin that causes the immediate termination of plant growth, necrosis and ultimately death of plant (Heimetal.,1995).The hydantocidin inhibits the twostep conversion of IMP to AMP in the purine biosynthesis. Hydantocidin itself did not affect adenylosuccinate synthetase or adenylosuccinate lyase. Moreover, the phosphorylate analog of hydantocidin seems to be powerful inhibitor of synthetase but not of lyase. It is non selective herbicide product having efficacy similar to glyphosate for controlling monocotyledonous and dicotyledonous weeds.( Siehl et al.,1996).

## II. CONCLUSION:

This review addresses the need for natural products that will aid in the development of herbicides with novel modes of action. The detectable increase in resistance to current herbicides needs the creation of new herbicides with novel modes of action. Compounds derived from nature are usually more readily degradable and results in decreased environmental damage. Natural compounds mentioned in this review having structural diversity shows significant activity and many of them could provide useful leads to the development of new herbicides. Numerous natural compounds show strong behavior as plant herbicides and it is predicted that more natural compounds will be commercialized near future .

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