Review of Literature:

Aristotle's disciple Theophrastus (372-285, BC), reported an example of the inhibitory effect of pigweed on alfalfa (Jelenic, 1987). An extensive review on plants used for pest control was done by (Yang and Tang, 1988) as described in *Shengnong Ben Tsao Jing* in 25-220A.D. in China. A total of 267 plants considered to have pesticidal activity were described by them, and many of them exhibited allelopathic potential. A famous Chinese pharmacologist called Lee Shi-Jen (1518-1593, AD), wrote a book on Chinese medicinal herbs, illustrating the toxic nature of chemical constituents to organisms. He also indicated that habitats might alter the plant constituents . De Candolle, a Swiss botanist, in 1832, suggested that the exudates of crop plants might be the prime cause of soil sickness in agriculture(Rice, 2012). Later,(Stickney and Hoy, 1881) reported a deleterious effect of black walnut trees on the growth of surrounding plants. (Schreiner and Reed, 1907) found some organic acids in soil , originally released by some plant roots, suppressed the growth of some ambient crops. Many years later, (Molisch, 1937) coined the term *Allelopathy* combining two Greek words - "Allelo" and "pathy" meaning "mutual harm", expressing that as a natural phenomenon of one plant releasing some inhibitory substances which inhibit the growth of other plants sharing the same habitat.(Rice, 2012) further defined the allelopathy as both inhibitory and stimulatory effects of one plant upon another including microbes. *Marasmin* is chemical produced by a microorganism and active against a higher plant; and *Koline* is for chemicals produced by higher plants and inhibitory against higher plants (Grümmer, 1955). On the other hand, autotoxication is the phenomenon of one plant producing toxic substance(s) which inhibit the growth of itself (Chou and Lin, 1976; Chou, 1999).

During 20th century, both allelopathy and autotoxication received a great attention in agricultural productivity, in particular to a continuous monoculture causing reduction of crop yield (Börner, 1960; Evenari, 1949; HR Bode, 1940).

Until late 1960, allelopathic concept about plants was for the first time applied to plant ecology in illustrating the mechanism of plant interference, dominance, succession, and climax formation (Muller, 1969). He and his students also contributed significant findings on other chaparral shrubs, like *Adenostoma fasciculatum* (McPherson and Muller, 1969). A classical paper entitled "Allelochemics: chemical interaction between species",was published by (Whittaker and Feeny, 1971) which stated that "chemical agents are of major significance in adaptation of species and organization of communities." For the first time a term "allelochemical" derived from allelochemics became popular in the science of agriculture, dealing with mechanisms of chemical interactions among organisms, such as plant-plant, insect-plant, insect- insect, microorganism-plant and microorganism-microorganism. Finally, allelopathy was defined by the International Allelopathy Society in 1996 as "any process involving secondary metabolites produced by plants, algae, bacteria, and fungi that influences the growth and development of agricultural and biological systems". In other words, compounds exhibiting allelopathy may regulate growth and development of plant, involving transpiration, photosynthesis, respiration, metabolism and even in molecular pathways of nucleic acid and protein and synthesis.

Plants also indirectly affect neighbouring plants by harbouring herbivores or pathogens or by modifying soil properties differentiating allelopathy from other mechanisms of plant-plant interaction, and also from abiotic factors (e.g., soil pH) which may affect the growth of plants. (Blum, 1998) pointed out that competition for nutrients may result in allelopathic interactions.

(A)<u>Factors that modify the effect of allelochemicals:</u>

With respect to its biochemical complexities the soil is called the "black box", (Regiosa et al., 1996) Most of all the allelochemicals processes are mediated by the soil but some volatiles can directly affect the target species. The soil can even dissolve affect the target species. The soil can even dissolve and adsorb some volatiles e.g. terpenoids in *Eucalyptus* species. The soil is responsible for the possible breakdown of molecules from previous inactive molecules as well as inactivation of phytotoxin to the release of toxicity from the previously inactive molecules (Weidenhamer, 1996). Depending on those processes the target species will be affected more or less. Adsorption by the soil and subsequent polymerization of allelochemicals can alter their phytotoxic capacity decreasing it, although it can also protect allelochemicals from degradation (Zhang *et al.*, 2009).

- As regards the availability and degradation of allelochemicals in the soil, certain factors like pH, oxygen concentration, temperature, microbial activity and soil- plant interactions are important (Kaminsky and Muller, 1977; Weidenhamer, 1996; Zackrisson and Nilsson, 1992). Phenolics can be adsorbed by charcoal, thus altering soil properties, mycorrhizae and trees and they affirm the "buffer and depot" effect between adsorptive media. Microbes and sources of carbon are critical to know the field effects of phytotoxins and their availability during the seasons. More information are required about the concentration of allelochemicals in the soil. Some studies have focussed on seasonal changes of allelochemicals (Dolling *et al.*, 1994; Nilsson *et al.*, 1998). Soil structure and texture can influence the absence or presence of an allelochemicals process (Inderjit and Weiner, 2001). Also, the light and oxidation can involve the activation or inactivation of some phytotoxins. The situation of target species can be determinant. A fixed concentration of an allelochemical can affect a stressed plant, if the species is suffering competition for water, light, nutrients or if the biotic or abiotic condition are harmful for the metabiolism of the plant (Inderjit and Weiner, 2001; Shibuya *et al.*, 1994). Experiments should be done as similar to nature as possible. For instance, allelochemicals affecting the permeability of the membrane (Baziramakenga *et al.*, 1995) in the roots can be effective due to lack of some nutrients, and the effect can be more pronounced if there is lack or excess of water and the combined result cannot be predicted by the individual measurement of each parameter. The combined effects can be synergistic (Einhellig, 1996).

(B) <u>Synergy between Allelochemicals:</u>

Allelochemicals provide protection against insects, herbivores and microbes Chemically diverse metabolites in plants occur in different mixtures of several structural types modified during evolution by natural selection (Firn and Jones, 2000; Papadopoulou *et al.*, 1999; Wink, 2003). Similar molecules with slight variations, serve as a protective chemical overlap and can be viewed as an evolutionary development of a a network of protection—chemical economy. This strategy proves highly adaptive. A study of sesquiterpene synthesis in plants showed that from a single substrate an enzyme produced 34 different compounds, and another produced 52 products from one single precursor (Croteau *et al.*, 2002). Such a catalytic flexibility yield products with multiple bioactivities. Even the individual interaction of a particular plant metabolite might be weak and unspecific and the sum total of interactions of numerous metabolites can lead to a substantial effect (Wink, 2003).

Modification of allelochemicals from one active compound to multiple active compounds, is favoured by conditional nature of the interrelationship between genes and environment resulting in an **economy of chemistry**. This is a broad-spectrum and efficient matrix of constituents that confer protective bioactivity against predators, providing plants with a selective advantage. Such strategy is common, rather than exceptional. Three of the allelochemicals expressed by a *Piper* sp. was demonstrated (Dyer *et al.*, 2003) to exhibit this economy of chemistry because they act synergistically exhibit a broad-spectrum protection against several pests.

(Wu *et al.*, 2002) pointed out that allelopathic effects actually result from groups of constituents, often showing synergy, rather than just a single chemical. An uplifment in selection pressure by just one single pest invokes an enhanced defense which may rely on synergy to increase defenses efficiently and economically against other pests (Poitrineau *et al.*, 2003). The efficient and economic organism is favoured by natural selection and is most likely to survive. Efficacy and economic ability are necessary due to the energetic cost of maintaining the biochemical pathways and subsequently the storage of these expensive allelochemicals. Therefore, if these costly allelophytochemicals have multiple functions, the survival chances are increase (Wink, 2003). This strategy gives protection against many pests in an environment and disallows resistance development in a specific pest, commonly occurring with the current strategy of using a chemical as an insecticide.

Ecophysiological Processes affected by allelochemicals during invasion :

Allelopathy is highly under debate these days in spite of its ecological relevance (Fitter, 2003; Fridley *et al.*, 2007; Tharayil, 2009). The physiological and ecological processes affected due to the release of secondary metabolites by invasive species to soil solution are different. Not only the diversity of plant species is disturbed by plant invasions but also there is an increase in the plant productivity (Rout and Callaway, 2009). Processes of invasion often increase the deposits and flow of nitrogen by processes controlled by the soil microbial communities favouring the productivity. Sometimes invasion processes inhibit the capacity of native plants by suppression of associated mycorrhizae to take up nutrients (Callaway *et al.*, 2008). In laboratory conditions, effects produced by allelochemicals have been detected on physiological processes in the native species like changes in the rate of germination or inhibition of germination percentage in the growth of seedlings. The inhibition of photosynthesis and interaction with the components of photosystem II by allelochemicals and the evolution of oxygen is one of the better studied proceses in allelopathy (Hussain and Reigosa, 2011; Lorenzo *et al.*, 2008, 2010a; Lu *et al.*, 2017; Zhou and Yu, 2006).

Benzoxazolin – 2 (3H) – one (BOA) has been shown to induce transcription of multiple genes related to cell detoxification and pathways of defense (Baerson *et al.*, 2005). Studies still need to be realized with allelochemicals from invasive weed species on lignifications, conductance of stomata, leaf transpiration, amino acid metabolism, hormone concentration regulation and cell cycle. The biodiversity is at a significant threat due to invasive species. Invasive weeds also change ecosystem processes (Raizada *et al.*, 2008), reduce native species abundance and richness by predatation, competition, hybridization, and indirect effects(Blackburn *et al.*, 2004; Gaertner *et al.*, 2009) change community structure (Hejda *et al.*, 2009) and change genetic diversity (Ellstrand and Schierenbeck, 2000). In Europe for example, a majority of the invasive weeds decreases diversity and alters community structure, whereas a lesser percentage directly affects threatened species (Vilà *et al.*, 2009). The increasing volume of transport and trade is also one of the major causes for the increase in number and spread of weed alien species, especially over the last 25 years (Hulme *et al.*, 2009). There are several reports on how respiration and ATP synthesis is effected by allelochemicals (Ishii-Iwamoto *et al.*, 2006), quantum yield, photosynthetic efficiency and dissipation of heat energy (Hussain and Reigosa, 2011), lipid and hydrogen peroxidation (Sánchez-Moreiras *et al.*, 2011), on the respiration of native species(Lorenzo *et al.*, 2008, 2010b). Studies on gene expression have shown that Benzoxazolin – 2 (3H) – one (BOA) induce transcription of genes associated with detoxification of cell and pathways of defence (Baerson *et al.*, 2005).

The way of action of some allelochemicals has been studied on redox system (reactive oxygen species), lignifications, conductance of stomata, foliar transportation, amino acid metabolism, regulation of hormone concentration and cell cycle, nevertheless these studies are not realized with allelochemicals from invasive species. Invasive species also pose a significant threat to biodiversity. Invasive species alter ecosystem processes (Raizada *et al.*, 2008), reduce abundance of native species and richness via, competition, predation, hybridization and indirect effects (Blackburn *et al.*, 2004; Gaertner *et al.*, 2009), change the structure of community (Hejda *et al.*, 2009). For example a reduction in species diversity and alteration of community structure is done by a large majority of the most invasive species in Europe, whereas a small percentage directly harms threatened species (Vilà *et al.*, 2009). Over the last 35 years an increase in the extent and volume of trade and transport is one of the root causes of increase in number and spread of alien species (Hulme *et al.*, 2009). Patterns of the extent of biological invasion, their impacts on biodiversity and the response of society to these impacts remain poorly quantified at the global scale.

The invasive Alien Species Indicator under the focal area "Threats to Biodiversity (Walpole *et al.*, 2009) present one of the first concerted and globally co-ordinated efforts to do so. Small scale experiments, have shown the relationship between the plant diversity of the community and non-native species invasion to be negative (Lorenzo *et al.*, 2010a), therefore, the resistance to the invasion of the system should increase with the diversity of species (Elton, 1958). Arguments that favour this old idea seems to reside in rich communities in species and few vacant niches are offered by it - niche complementarity effect; or a greater probability exists that there is complete exclusion of an ivading plant by a superior competitor - Sampling effect (Fargione and Tilman, 2005). Short period studies indicate a relatively small impact of invasive plants on ecosystems, nevertheless the future invasiveness on the native flora could be very high (van Wilgen *et al.*, 2008) and until now indications obtained suggests that the effect on biodiversity would have to be a reason for preoccupation.

The effect of invasion process on the effect of autochthonous diversity, leads to the possibility of interaction with other stress factors like drought, more pronounced in a global warning context (van der WAL *et al.*, 2008) that affect the native species should be taken into consideration (Maron and Marler, 2007). Although in the field of ecophysiological interactions within the frame of invasive species a wide scope exists, plant communities do not respond similarly according to the available present data, resulting in significant changes in then dominance and compositon of the species (Matesanz *et al.*, 2008). Blackwood (*Acacia melanoxylon* R.Br.) which is considered invasive in Galicia (de Galicia, 2007) has its origin in the temperate forests of south-east Australia and Tasmania. It currently covers a considerable area as monocultures as well as in mixed stands with *Eucalyptus globulus* in the coastal zone of north-western Siberian Peninsula. It quickly establishes in the alien environment upon invasion, resulting in the structural and dynamics change of native ecosystems. The inhibitionry effects on seedling establishment and ecophysiological characteristics (growth, leaf water contents, photosynthetic efficiency, quantum yield, protein contents and carbon isotope discrimination) of native species. The presence of growth inhibitory phenolic and flavonoid compounds present in the flowers and phyllodes of *A. melanoxylon* R. Br. was concluded as the cause of inhibition. The differences in the ecophysiological features as confirmed through laboratory tests where a positive relation has been elaborated between production and plant diversity and a negative relationship between plant diversity and invasion has also been verified. None the less the underlying mechanisms underlying the invasion process are different according to the type of invaded community (Jiang *et al.*, 2007). The allelochemicals of invasive species exert a strong impact on the dynamics of nutrient cycling in the soil of the invaded area. The great diversity of invasive plant species and susceptible places for invasion showed an inconsistency in the patterns of differentiation as proposed among invaded and free areas by exotic species. The concentration of C, N and P, generally increases generally with the growth of the invading species (Li *et al.*, 2007). Studies on nitrogen fixing invasive plants indicate that areas of invasion showed a high content in N and a low C:N ratio. This results in the change of soil microorganisms due to the above mentioned variations with an increase in the contents of organic C, N and interchangeable cations (Marchante *et al.*, 2008). These changes can be produced by different forms, for example by changing the radical system or varying the organic matter entry into the invaded ecosystem. Some non-fixing invaders have also been found to augment the total C,N and net nitrification rate (Chen *et al.*, 2009). Although some invasive and non-invasive species have the same effect on the soil nutrients, we cannot confirm that a phenomenon which is generalized exists. Interestingly other authors have published different results in the invaded areas where total N, P, N (NO_3^-) available P, with decrease in the stability of aggregates. With an increase in organic C and N(NH_4^+) (Zhang *et al.*, 2009). The interaction of the plants with the associated soil communities, where plants influence soil organisms and vice versa can result in dynamic feedbacks (Bever *et al.*, 1997; Wardle *et al.*, 2004). The result of these interactions can be negative to neutral or positive. When the benefits brought about by symbionts and decomposers overwhelm the negative effects of soil pathogens and herbivores of roots an enhance the performance of plants, the interaction is considered positive, whereas negative interactions are when the sum total of the effects of all soil pathogens, root herbivores, symbiotic mutualists as well as decomposers reduce plant performance. Negative interactions enhance plant community diversity by exerting density dependent control (Klironomos, 2002) and speed up succesional replacement(Van der Putten *et al.*, 1993). The rate of promotion of soil borne pathogens differs among species, functional groups (Kardol *et al.*, 2007).

Most of the assessments on invasion effects by alien plants has been done on the animal and plant's biodiversity. Attention has only been recently devoted to the effects of plant invasion on soil microorganisms that could play a basic role in the invasion process

(Rodríguez-Echeverría, 2009). Enzyme activities in the soil has been used as effective indicators of the capacity of the microbiota to mineralize mineral and carbon nutrients, and thus they can be used as yardsticks of microbiota functionality (Kourtev *et al.*, 2003). Invasive plants can change the microbial community surrounding the roots through root exudates (Bais *et al.*, 2004). Results indicate an increment in microbial biomas, increase in the density of invasive species in invaded areas (Li *et al.*, 2007), metabolic activity -basal respiration (Jacinthe *et al.*, 2010) and the functional diversity (Zhang *et al.*, 2009). Positive feedback cycles with the soil in which invasive species invade are being established as indicated by recent research. Also the rhizosphere of the invasive species becomes rich in mutualistic organism to get benefit from them. A high fungi/bacteria ratio has been found in invaded soils as compared to microbial communities in invaded soils or where there is a difference in the native flora. None the less different ecosystems which are invaded indicate that the ratio of fungi/ bacteria cannot be generalised and typopology of the invaded zone and the degree of time of the invasion are the key factors on which it depends (Lorenzo *et al.*, 2010b). Recently new research has emerged that frequently does not mention allelopathy but focuses on putative secondary metabolites as means of short or long distance communication via signalling between plants above the ground by volatile compounds (Pierik *et al.*, 2013) or below ground by volatile or non-volatile compounds (Achatz *et al.*, 2014; Babikova *et al.*, 2013; Barto *et al.*, 2012).

VIII. <u>Factors mediating the release of allelochemicals and their production:</u>

Several abiotic and biotic factors may influence the production of allelochemicals. The information of these changes is better observed in phenolics, but more so in other compounds. Studies have shown that various nutrients deficiency, as well as water stress, UV radiation, physical damage by herbivores or interspecific competition can enhance the production of allelochemicals and the sensitivity to allelochemicals (Cummings *et al.*, 2012). In the regulation of phenolics in allelopathy a general trend is associated with its content and in stressed conditions the plant produce more phenolics (Fu *et al.*, 2019) Allelochemicals production is mediated through the following factors:

1. **Light:** According to the intensity, wavelength, and photoperiod or phytochrome mediated responses, when being near red light, there is increased quantity of phenolics while UV as well as ionizing radiations alleviate the quantity of growth-inhibiting phenolics (Cummings *et al.*, 2012).
2. **Nutrients:** Deficiency of nutrients augment the production of phenolic allelochemicals (Abbas *et al.*, 2017).
3. **Water stress:** Production of allelochemicals are enhanced during water deficits (Abbas *et al.*, 2017)

4. Temperature extremes: Extreme temperatures increase allelochemicals synthesis. Like chlorogenic acid in the tissues of plants were increased in low temperature and at freezing temperatures (Zobel *et al.*, 1997) found changes in several phenolic allelochemicals.

5. Herbicide or pesticide treatments: In the receptor plants herbicidal application can augment the accumulation of allelopathic agents (Reigosa *et al.*, 2006; Soltys *et al.*, 2013).

6. Disease: Illness and parasite attack, can cause an acceleration in the allelochemical production (Einhellig, 1996).

Allelochemicals are classified into nine classes according to structural properties (Li *et al.*, 2010).

(1) water-soluble organic acids, aliphatic alcohols, aldehydes, ketones;

(2) unsaturated simple lactones;

(3) anthraquinone, benzoquinone, and complex quinines;

(4) phenolic compounds;

(5) coumarins;

(6) cinnamic acid and its derivatives;

(7) flavonoids;

(8) tannins;

(9) steroids and and also terpenoids like-sesquiterpene lactones, diterpenes, and triterpenoids.

Plant secondary metabolites include about 200,000 compounds, among which the most diverse are terpenoids (30,000), alkaloids (21,000), and phenolic compounds (8000) (Holopainen *et al.*, 2018).

Review of Literature of the three weeds taken for study:-

I-First weed.

A) Scientific Name:

***Desmostachya bipinnata* (L.) Stapf**

B) Common Name:

Halfa grass.

C) Local Common Names:

India: dhab; durbha; kusha.

D) Taxonomic Tree

Domain: Eukaryota

Kingdom: Plantae

Phylum: Spermatophyta

Subphylum: Angiospermae

Class: Monocotyledonae

Order: Cyperales

Family: Poaceae

Genus: Desmostachya

Species: *Desmostachya bipinnata*

E) <u>Distribution</u>:

This is a monotypic genus widely distributed throughout India, also found in Egypt and Syria, Pakistan, Persia, Middle East to Indo-China and North and tropical Africa (Kirtikar and Basu, 1918).

E) <u>History of Introduction- its risk and Spread</u>:

No specific information is available regarding the introduction of *D. bipinnata*. There is a possibility of the weed being introduced due to seed contamination of crop seeds or by practices in agriculture that break the rhizome into fragments. It is indeed a noxious weed. Since information is not available on the impacts and spread of this weed therefore it may not yet appear on lists of regulated weeds and so may become introduced in new areas.In the native range, spread of the species rapidly increases the density of the weed in disturbed sites and some dispersal to new locations, rather than any introduction to new, exotic habitats. As an example, places where timber extraction and overgrazing have caused degradation of sal (*Shorea robusta*) forests in India, the damaged area may become dominated by *D. bipinnata.,* Possibly due to the allelopathic effects on seed germination, *D. bipinnata* was found to be invasive on, salt-affected, reclaimed soils planted with *Leptochloa fusca* (Akhter *et al.*, 2004; Mahmood, 1998).

F) Habitat:

D. bipinnata is common in abandoned agricultural fields and wastelands and (Sastry and Kavathekar, 1990), sand dunes, brackish wetlands in inlands and marshes and on salt-affected reclaimed wastelands (Akhter *et al.*, 2004). It grows in dry places frequently and in open wastelands subject to periodic disturbances like grazing, cutting and burning. D.

bipinnata flourishes well in hot and dry conditions, forming big tussocks in sandy arid areas.

G) Habit:

Herbaceous, tufted perennial grass with thick scaly root stocks, sending out creeping rhizomes in all directions. Leaves - many; may reach up to 50 cm in length and 1 cm in breadth at the base (Prajapati *et al*., 2003). Propagated by seed or vegetative propagation.

H) Environmental Requirements:

It is widely distributed in dry, arid regions of India with an annual rainfall of 2.5cm-7.5cm (Dabadghao and Shankarnarayan, 1973). It is, however, extremely tolerant to drought and known to survive even where annual rainfall is low as 54 mm, and is also found in higher rainfall zones, above 1000 mm. It is very saline soil tolerant (Mahmood, 1998), alkaline to calcareous and highly sodic soils (Kaur *et al.*, 2002; Sinha *et al.*, 1991) It constitutes the dominant weed in saline soils which are alluvial with restricted water penetration occuring in dense patches (Mahmood, 1998).

I) Species Affected by this weed:

D. bipinnata is a common weed in the agricultural fields of cotton (*Gossypium hirsutum*), sorghum (*Sorghum vulgare*), fallow lands of wheat (*Triticum aestivum*) and *Pennisetum typhoides* and on bunds in fields of rice (*Oryza sativa*).It is a dominant weed in agricultural fields (Hussain and Rashid, 1989) .It is commonly found in tree plantations, grasslands, and agroforestry ecosystems.

J) Biology and Ecology:

a) **Genetics**:

Chromosome number is 2n=20 (Christopher and Abraham, 1974).

b) **Phenology**:

From May to July, flowering and fruiting occurs, maturing from the month of August to October. On moderately alkaline calcium rich soils, the rains during the monsoon trigger active growth of *D. bipinnata* in June and attains a peak during the rainy season during September (Sinha *et al.*, 1991). The leaves senesce in dry weather with the onset of winter months from November to February followed by a vigorous growth in summer months because of regeneration of shoots from the rhizomes . Since it is a deep-rooted grass, almost 55% of the root biomass remains concentrated in the top 10 cm of the soil, whereas the roots and rhizomes penetrate deeper than 1.5 m (Gupta *et al.*, 2015) .

c) **Physiology:**

A - C_4 photosynthetic pathway is exhibited by *D. bipinnata* (Dallwitz, 1993), like most other grass species found in the moderate, temperate and moist Himalayan region in India (Das and Vats, 1993). The occurrence of this weed has been positively correlated with increased exchangeable ion, like sodium, chlorine, magnesium and calcium and ion content. It has a high salt tolerance (Aronson and Whitehead, 1989). In alkaline soil. *bipinnata* due to the presence of polyphenol oxidase activity gas a significant role in salt resistance (Singh, 1994).

d) **Biochemical analysis:**

Allelochemical screening of the weed *Desmostachya bipinnata* (L) reveal various classes of chemicals such as alkaloids, flavonoids, glycosides, saponins, terpenoids (Hegde *et al.*, 2010). (Singh *et al.*, 2014) reported tannins, flavonoids, steroids, glycosides, and coumarins from the weed. Through High Performance Liquid chromatography (HPLC) the presence of coumarins, scopoletin, flavonoids like kaempferol, quercetin, glucoside and trycin compounds were confirmed by (Hifnawy *et al.*, 1999; Packialakshmi, n.d.). (Golla *et al.*, 2013) reported sterols like- stigmasterol, β-sitosterol, daucosterol etc. A new compound "xanthene 2,6-dihydroxy-7-methoxy-3H-xanthen-3-one" was recently isolated along with 5-Hydroxymethyl 2-furfural, β-amyrin, β-sitosterol, β-sitosterol ethanolic extract of the grass (Shakila *et al.*, n.d.).

e) Reproductive Biology:

D. bipinnata particularly in north Indian populations, show abortive embryo sacs due to female gametophyte degeneration, due to self-incompatibility caused due to the failure of the pollen tube to reach the embryo sac (Bhanwara, 1986). This observation signifies the importance of understanding further the reproductive biology of the weed in relation to its widespread occurrence in India, South-East Asia and Africa.

f) <u>Environmental and Social Impact:</u>

The presence of *D. bipinnata*, particularly in alkaline and sodic soils has some environmental benefits. nutrient cycling patterns and productivity in a *D. bipinnata* grassland (soil pH 9.3) has shown that soils which are sodic are potentially productive under this adaptive native vegetation and give protection to native vegetation on wastelands affected by soil sodicity by improving soil organic matter.The introduction of this weed with agroforestry species has shown to improve the physiobiogeochemical properties of sodic soils (Kaur et al., 2002a,b). A novel and efficient biosorbent was developed from NaOH modification of *D.bipinnata* (Kush grass) leaves for removal of Cd(II) ions from the soil (Pandey *et al.*, 2015). The very sharp tillers along with coarse leaves can cause small but painful cuts in contact with the skin, being a nuisance to farmers especially during weeding operations.

g) Environmental Risk: In its native range the weed is invasive, has adaptability to varying environments tolerates browsing pressure, mutilation, fire and or benefits from, cultivation, locally mobile has high reproductive vigour, with propagules that may remain viable for more thanone year. It is prone to transportation accidentally, difficult to detect as acommodity contaminant and costly to control.

II-Second weed :

A) Scientific Name:
Parthenium hysterophorus L.

B) Common Name:
Congress grass.

C) Local Common Names:
India: bhoothkeda; carrot weed; chatak chandani; gajar ghas; keepa geda

D) Taxonomic Tree:
Domain: Eukaryota
Kingdom: Plantae
Phylum: Spermatophyta
Subphylum: Angiospermae
Class: Dicotyledonae
Order: Asterales
Family: Asteraceae
Genus: Parthenium
Species: Parthenium hysterophorus

E) Distribution:

The species is listed to have originated in the east of Mexico and the Antilles, with secondary native distribution from southern USA to South America (National Commission of Biodiversity of Mexico, 2018). It was accidentally introduced into India and Australia in the 1950s, as a grain contaminant or pasture seeds and has therefore achieved major weed status in those countries. Recent reports indicate the presence of the weed from other countries indicate that its geographic range continues to increase. At present the weed is found in Africa, Asia, North, South and Central America, the Caribbean, Europe and Oceania (European and Mediterranean Plant Protection Organization-EPPO, 2018; Missouri Botanical Garden, 2018). In India it is widespread and invasive, in almost all states,including our own state of West Bengal (EPPO, 2014).

E) History of Introduction- its risk and Spread:

The weed is thought to have entered India along with imported food grains as a contaminant duringthe 1950's from the USA (Vartak, 1968). It was first reported in India in 1810 in Arunachal Pradesh (Gnanavel and Natarajan, 2013).

F) Habitat:

P. hysterophorus is an annual herb, prolific in disturbed habitats like roadsides ,railway tracks, river banks and creek, stock yards, on any wasteland and invades agricultural systems (EPPO, 2018). It is also present in coastal dunes, villages, gardens, along streams, plant nurseries and fields of crop. It is also present in wetlands (Rashmi *et al.*, 1999). Drought and reduced pasture cover that follows creates the ideal conditions for the species establishment (Kaur *et al.*, 2014). It grows in hot, arid, semi-arid to humid habitats, in altitudes upto 4286 metres above sea level (PROTA, 2018).

G) Habit:

Erect, branched, annual ,sometimes perennial, herbaceous plant with a deep taproot and seed propagated with vigorous growth. In neotropical areas it grows to 30-90 cm in height (Kissmann and Groth, 1992), but up to 1.5 m to 2.5 m, in exotic situations (Navie *et al.*, 1996).

Both stems and leaves are covered with short, trichomes, four types of which have been recognized and are considered to be of taxonomically important within the genus (Kohli and Daizy, 1994).

Flower heads - both terminal and axillary, pedunculate and slightly pubescent, composed of multiple florets forming small white capitula, 3-5 mm in diameter. Thousands of inflorescences, in branching clusters, are someties produced at the tip of the plant during the season.

Seeds are achenes, black, about 2 mm long, each with two thin spathulate appendages at the apex which act as air sacs aiding in dispersal.

I) Species Affected by this weed:

In India, the yield losses are reported as up to 40% in several crops and a 90% reduction of forage production (Gnanavel and Natrajan, 2013).

H) Environmental Requirements:

P .hysterophorus is able to germinate and grow over a wide range of temperatures and photoperiods. It flourishes in the humid and sub-humid tropics, showing a noteworthy preference for cracking, alkaline, black, clay soils of high fertility, but is able to grow on a wide spectrum of soil types from sea level up to 2500 m (Taye *et al.*, 2002). This weed has several in-built properties with efficient .It grows best in subtropical regions with mean annual temperatures of 10-25°C and an annual rainfall above 500 mm. Areas receiving less than 500 mm of rainfall are probably unsuitable, although the weed has strong adaptive methods for tolerating both moisture stress (Kohli and Daizy, 1994) and saline condition (Hegde and Patil, 1982).

Plant name	Family
Abelmoschus esculentus (okra)	**Malvaceae**
Allium cepa (onion)	**Liliaceae**
Anacardium occidentale (cashew nut)	**Anacardiaceae**
Arachis hypogaea (groundnut)	**Fabaceae**
Carica papaya (pawpaw)	**Caricaceae**
Carthamus tinctorius (safflower)	**Asteraceae**
Cicer arietinum (chickpea)	**Fabaceae**
Citrullus lanatus (watermelon)	**Cucurbitaceae**
Cocos nucifera (coconut)	**Arecaceae**
Eleusine coracana (finger millet)	**Poaceae**
Eragrostis tef (teff)	**Poaceae**
Gossypium (cotton)	**Malvaceae**
Helianthus annuus (sunflower)	**Asteraceae**
Lens culinaris subsp. culinaris (lentil)	**Fabaceae**
Mangifera indica (mango)	**Anacardiaceae**
Medicago sativa (lucerne)	**Fabaceae**
Momordica charantia (bitter gourd)	**Cucurbitaceae**
Musa (banana)	**Musaceae**
Oryza sativa (rice)	**Poaceae**
Phaseolus (beans)	**Fabaceae**
Psidium guajava (guava)	**Myrtaceae**
Saccharum officinarum (sugarcane)	**Poaceae**
Solanum lycopersicum (tomato)	**Solanaceae**
Senna occidentalis	**Fabaceae**
Solanum tuberosum (potato)	**Solanaceae**
Sorghum bicolor (sorghum)	**Poaceae**
Triticum aestivum (wheat)	**Poaceae**
Zea mays (maize)	**Poaceae**

Source: Centre for Agriculture and Bioscience International CABI, 2019.

J) <u>Biology and Ecology:</u>

a) Genetics:

The chromosome number has been reported as 2n=18 in India (Hakoo, 1963) and Australia (Navie *et al.*, 1996) in *P. hysterophorus* .Germplasm collections are available at various institutions (Kew Royal Botanic Gardens, 2018; USDA-ARS, 2018). Information about its DNA is available at the Barcode of Life Data System (BOLDS, 2018).

b) Phenology:

The weed is an aggressive colonizer in disturbed grounds, successfully germinate, grow and flower over a broad range of photoperiods and temperatures, all year-round if moisture is available (Tamado *et al.*, 2002; Taye *et al.*, 2002). Four or more successive cohorts of seedlings may be produced in a season (Pandey and Dubey, 1989). Plants emerging during the first spring usually attain a greater size and have a significantly longer lifespan than those produced in the summer. Weed biomass production increases with increasing temperature up to an optimum day/night temperature regime of 33/22°C (Williams and Groves, 1980). In dry conditions, the life cycle usually takes up to 335 days, compared to 86 days under optimal conditions.

c) <u>Physiology:</u>

P. hysterophorus is characterized by a low photorespiratory activity and has C_3 photosynthetic pathway but with positive C_4 tendencies (Hegde and Patil, 1982). The species also produces alelochemicals that when released in the soil have allelopathic effects on other species (Rubaba *et al.,* 2017).

d) <u>Biochemical analysis:</u>

Parthenin, a sesquiterpene lactone, chlorogenic and ferulic acid are the primary allelochemicals that act as inhibitors present in *Parthenium hysterophorus* (Kanchan and Jayachandra, 1981). Phenolic compounds are present such as caffeic acid, p-coumaric acid, anisic acid, p-anisic acid, vanilic acid ,ferulic acid and chlorogenic acid (Mersie and Singh, 1987). The sesquiterpene group includes parthenin, coronopilin, 2-β hydroxyl coronopilin, tetraneurine A, hysterones A-D (Venkataiah *et al.*, 2003).

e)<u>Reproductive Biology</u>:

It reproduces by seeds .It is unable to reproduce by apomixis or vegetatively from plant parts but is a prolific producer of seeds -15,000-25,000 achenes / plant on an average, and up to I lacs in large plants, (Gnanavel and Natarajan, 2013) and continues to flower and fruit till senescence.

f) <u>Environmental and Social Impact:</u> The weed that can cause irreversible habitat changes within native grasslands, woodlands, banks rivers and of floodplains in India (Kumar and Rohatgi, 1999). Huge stands of *P. hysterophorus* are common in almost all open areas. Due to its allelopathic power, it replaces dominant flora suppressing natural vegetation in wide ranges of habitats and thus is a big threat to biodiversity. (Batish *et al.*, 2005) recorded 39 types of species in a *Parthenium*-free area, but in an infested area only 14 were present, and very scarce or sometimes nil vegetation can be seen in some *Parthenium*-dominated areas (Kohli and Daizy, 1994). Wherever it invades, it replaces indigenous grasses and weeds, which are eaten by the grazing animals (De, 1983). It has an adverse effect on the health of grazing animals which develop severe dermatitis, lesions in the gastrointestinal tract, kidney and liver that can lead to death. Allelochemicals produced by the species which are washed away by water might get into aquatic ecosystems causing detrimental effects on aquatic plants, as well as on the the soil microbial activity (Joshi *et al.*, 2016).

g) Environmental Risk:

P. hysterophorus has infested about 35 million hectares of land in India. From the experiences in India, Australia and Africa, a considerable risk of accidental introduction of the species is there (EPPO, 2018; GISD, 2018). It can be spread via flowing water or blown by wind, making prevention of spread difficult. After introduction, it can be spread by vehicles, farm machinery, transport of goods, sand, soil and compost from infested to uninfested localities. The rapid colonization is aided by the mobility of the seed, the adaptability of the species to a wide range of habitats, its drought tolerance, the high growth rate and the allelopathic effects it has over other species (Rubaba *et al.*, 2017).

III-Third weed :

A) Scientific Name:

Alternanthera sessilis **(L.) R. Br. ex DC.**

B) Common Name:

Sessile joyweed

C) Local Common Names:

India: Garundi, Phakchet , Kanchari, Sanchi Shak , Madaranga , Koypa

Taxonomic Tree:

Domain: Eukaryota

Kingdom: Plantae

Phylum: Spermatophyta

Subphylum: Angiospermae

Class: Dicotyledonae

Order: Caryophyllales

Family: Amaranthaceae

Genus: Alternanthera

Species: *Alternanthera sessilis*

E) Distribution:

A. sessilis has a pantropical distribution throughout the Old World tropics, tropical Africa, southern and eastern Asia and Australia Recent studies suggests that it originated in South America from where it was introduced to the Old World (Sánchez-Del Pino *et al.*, 2012). In India it is found invasively in the states of - Arunachal Pradesh, Assam, Himachal Pradesh, Jammu and Kashmir, Manipur, Meghalaya, Mizoram Nagaland, Sikkim, Tripura, Uttarakhand and West Bengal (Sekar, 2012).

E) History of Introduction- its risk and Spread:

The risk of introduction of this weed is moderate. Commercially it is used for ornamental purposes, and its seeds are naturally spread by wind or water. Therefore *A. sessilis* colonizes new areas near cultivated lands. In the USA, the species is considered as a noxious weed (USDA-NRCS, 2014).

F) Habitat:

A. sessilis is a common omnitropical weed of soils which are shady and damp in cultivated and waste areas. It occurs in common associations along roadsides, pathways, irrigation canals, ditches, gardens, swamps, and fallow land. The weed is both hydric and xeric adapted (Datta and Biswas, 1979). It is also found in swampy rice fields in Asia and West Africa in the following cultivated areas: maize crops in Nigeria; sorghum, millet, *Eleusine* sp., cotton, maize, groundnuts, cassava and cash crops in Zaire; and tobacco, vegetable farms and pastures in the Philippines. It is typically found on wetland habitats, including in water up to almost one meter deep (Gupta and Palit, 2014).

G) <u>Habit</u>:

Stems lie flat, 1-10 cm long. Leaves are mostly elliptic sometimes spear-shaped - 0.3cm - 3cm wide. Petioles are 1-5mm long. Bracts are shiny white under the sessile spikes of the flower. The sepals are 2.5-3mm in length (PIER, 2006). *A. sessilis* has a glistening fruit, that is light-beige yellow (FNWD, 2004). The fruits are indehiscent, a small, flattened, obcordate utricle, 2-2.6mm long, enclosing the seed. Seeds are dark-brown or black, shiny and disc-shaped, about 0.8-1.2 mm in diameter, light sensitive and the average number of seeds / plant is about 2000.

H) <u>Environmental Requirements</u>: *A. sessilis* can grow on a wide range of soil types, preferring damp conditions. It can be found at low and medium altitudes in the Philippines, and 0-2650 m in the Irian Jaya, Indonesia. Loamy, alkaline soils, low in exchangeable calcium and rich in nitrogen content are most favourable for its thriving. This species is able to grow in flooded areas (up to 90 cm deep), but it is also tolerant to xeric conditions (PROTA, 2014).

I) Species Affected by this weed:

Plant name	Family
Arachis hypogaea **(groundnut)**	**Fabaceae**
Eleusine coracana **(finger millet)**	**Poaceae**
Gossypium herbaceum **(cotton)**	**Malvaceae**
Manihot esculenta **(cassava)**	**Euphorbiaceae**
Nicotiana tabacum **(tobacco)**	**Solanaceae**
Oryza sativa **(rice)**	**Poaceae**
Panicum miliaceum **(millet)**	**Poaceae**
Sorghum bicolor **(sorghum)**	**Poaceae**
Zea mays **(maize)**	**Poaceae**

Source: Centre for Agriculture and Bioscience International CABI, 2019.

J) Biology and Ecology:

a) Genetics:

Chromosome number reported for *A. sessilis* varies from 2n = 34 to 2n = 40 (Flora of China Editorial Committee, 2014).

b) Phenology:

In India, *A.sessilis* flower and fruit year round with most vigorous vegetative growth with the onset of the monsoons , while the most vigorous reproductive growth during the end of the season. Self-pollination occurs in the flowers and the fruits are dispersed by both wind and water.

c) Physiology:

A. sessilis has C_3 photosynthetic pathway but with positive C_4 tendencies as in other closely related species like *A. ficoides and A. tenella* with less Kranz like anatomy in leaves and resembles other known C_3-C_4 intermediate species which show C_3^- C_4 intermediate photosynthetic pathway. (Rajendrudu *et al.*, 1986; Sage *et al.*, 2011; Sánchez-Del Pino *et al.*, 2012).

d) Biochemical analysis:

Allelochemicals in the leaves, stems and roots of *A. sessilis*, have been well documented in literatures viz -biologically active flavonoids such as gallic acid, luteolin, rutin and kaempferol. Anthraquinone – a derivative of shikimic acid, β-sitosterol an alkaloid with six isoprene units formed from mevalonate the pathway and a phenol - quercetin and myricetin obtained from cinnamic acid derivatives have been studied by researchers (Materska, 2008; Wolfreys and Hepburn, 2002).

e)Reproductive Biology:

A. sessilis is an annual or sometimes perennial herb, 0.3-1 m in height, with creeping tap roots which are strong. Prostrate stems, rooting at the nodes, floating sometimes, ascending or creeping at the tips, cylindrical and pubescent, with numerous upright branches. Vegetative propagules, seeds, fruits etc are dispersed by ants. (Pancho, 1986; Soerjani *et al.*, 1987). The average seed number produced per plant is 2000.

f) Environmental and Social Impact:

A. sessilis is an environmental and agricultural weed and an invasive plant principally in wetlands. It blocks irrigation ditches and dams; replaces native vegetation; and interferes with cultivated crops and pastures in low-lying, ill-drained areas. In paddy fields in Taiwan it is the most predominant weed. It causes moderate yield along with quality losses in certain other rice producing countries (Mehmood *et al.*, 2017). In Nigeria it is a weed of maize crops and in Congo it has been recorded to be growing in the fields of a variety of cash crops (Gupta and Palit, 2014).

g) <u>Environmental Risk:</u>

According to :- Global Invasive Species Database (GISD) 2015:-

- Damages ecosystem.
- Modifies hydrology.
- Forms monoculture.
- Negative impact on agriculture.
- Reduction of native biodiversity.
- Loss of species which are native.

<u>Likelihood of entry</u>

- Prone to be transported accidentally or deliberately across international borders.
- Difficult to be detected as a contaminant of commodity or in the field.