HERBICIDAL CONTROL OF GRASSES

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Necessity of the herbicidal application for controlling undesirable grasses, by the Defence Services, Military farms and Inter Service Organisations is highlighted. Control of grasses by herbicidal chemicals, registered under the Insecticides Act 1968 in this country, is reviewed apart from a mention of non-chemical methods.

Grasses are monocotyledonous annuals or perennials[1,2] belonging to *Graminae* with eleven distinct tribes and are the most universally diffused of all the flowering plants. In the tropics grasses are second in abundance to *Leguminosae*. Their principal requirement is availability of abundant moisture in soil.

Grasses infest all the field crops, fruit crops, plantation crops and forests. Besides, grasses grow profusely in non-agricultural croplands, asphalt and brick pavements, turf, golf courses, shoulders of runways, air ports, fence rows, rail roads, vehicle tracks, mule tracks, highways, pastures, firing ranges, Army, Air Force, Naval training centres/academies, Service stores holding installations, Base/Field/Command/Army hospitals, etc.

Currently weeding out undesirable grasses in the Defence Service offices/installations/units is through the laborious time-consuming manual and mechanical methods which are, however, far from effective. The object of this review is to highlight current trends of chemical control of grasses with herbicides apart from a brief outline of mechanical and physical methods in vogue.

Common Grasses of India and Herbicide Research in India

It is necessary to know the grasses considered weeds in our country of specific significance to the Armed Forces both from the point of view of the military farms and the non-agricultural ones. In the North-West plains of our country, the following grasses are considered[2(a)] to be prominent *Kharif* or rainy season weeds of crops like maize, sorghum, bajra, sugarcane, and several vegetables like : tomato, chillies, brinjal and others *Eleusine verticillata* (Makra*), *Panicum repe-ns, Cenchrus biflorus* (Anjan ghas*), *Dactyloctenium aegyptium* (Makra ghas*), *Digitaria adscendens* (Surwari*), *Echinochloa crusgalli* (barnyard grass; Sama ghas dhelari*), *Eragrostis ciliaris* (Panglas*), *Eragrostis diarrhena, Eragrostis poaeoides, Eragrostis tenella* (Phephani*) and *Eragrostis tremula* (Dholphulio*) besides perennials like *Cynodon dactylon* (Bermuda grass; doob*), *Eragrostis cynosuroides* (Dhab*), *Saccharum spontaneum* (Kans, patura) and *Sorghum halepense* (Johnson grass; baru*).

The following grasses are reported as summer weeds in North-West India[2(a)] infesting orchards as well as lawns : *Imperata cylindrica* (Thatch or Lalang grass; bharavai*), *Paspalidium flavidum, Setaria tomentosa, Sporobolus diander* and *Eleusine indica* (crab grass; mandle*). The standard lawn grass in various parts of this tract is *Cynodon dactylon* (the common *hariali* or *dhoob* grass). *Poa annua* is a winter weed growing in the lawns and public parks.

Pennisetum purpureum[3] (Napier grass or elephant grass) is a pernicious tall weed in the North-Eastern plains of Assam and Meghalaya. The Agricultural Research unit, Almora identified around one hundred species of grasses[4] (some of them as weeds) at heights varying from 1676-2746 m in the Kumaon sector. *Poa* species predominate followed by *Panicum, Festuca* and *Eragrostis* species. Thirteen species of grasses (*Digitaria, Eragrostis* and *Echinochloa spp*) were reported in upland intermediate and low land crops in Chota Nagpur plateau of North Bihar[5]. *Cynodon dactylon* (Bahama grass) was found in Karnataka[6]. *Echinochloa crusgalli* in Kerala[7], *Digitaria, Eleusine* and *Echinochloa spp* in Orissa[8] and *Echinochloa* and *Cynodon sp.* in Haryana[9] were identified in agricultural crop lands. The major sub-tropical and tropical grasses in the world (viz., Bermuda grass, Bahama grass, quack grass, couch grass, barnyard grass, Johnson grass and foxtails) are equally rampant in our country as well.

*Local Hindi names for the grasses.

Regional Research Laboratory, Jorhat[10] (Assam), Defence Science Laboratory, Delhi, Defence Materials and Stores Research & Development Establishment, Kanpur, National Chemical Laboratory, Pune, are actively engaged in researches on herbicides for the eradication or control of grasses. Control of grasses and weeds in Tamil Nadu in the past few decades was reviewed[11]. Weed Science Conference and Workshop was conducted at Hyderabad in 1977 by Indian Society of Weed Science with active colloboration from Indian Council of Agricultural Research, World Health Organisation and International Crop Research Institute for Semi arid Tropics[12].

Non-chemical Methods for Controlling Grasses

These include physical or mechanical methods and biological methods. Employing goat weed beetle for range weed, cactus moth for cacti, cinnabar moth for Tansy ragwort are some of the examples of biological methods of weed control other than grasses[11]. However, no specific biological method of grasses appears to be on record.

Deep ploughing below 30 cm of the soil is a mechanical method for the control of quack grass[13]. Cultivation[13] is also a mechanical method in preventing flowering and seeding of annual grasses, but the efficiency of cultivation depends on the depth of cultivation, timing and frequency of cultivation. Removal by bare hands or use of pointed sticks, curved mild steel blades, knives, metal hoes, machetes, metal hoes attached to animals, lawn mowers, agricultural and horticultural appliances (power operated) and manual implements etc., are the other mechanical methods for the removal of grasses. Mechanical methods including mowing are somewhat effective in controlling annual grasses but not very effective in the case of perennial grasses and grasses of identical taxonomy (e.g., smaller grains belonging to *Graminae*) as it is difficult to distinguish and differentiate the desired crop from the undesirable grass.

Mechanical methods like mowing are useful only for the control of low growing prostate rosette type of grasses in lawns, turfs, play grounds, golf courses and road sides. Mowing should be low enough to cut off the flowers of the grasses and timed in such a way to remove the flowers before seed formation and seed dispersal. Application of heat[10] (45-55°C) leads to the coagulation of protoplasm and kills grasses. This method is applied through the use of flame throwers or flame torches or steam and is useful for gravel roads and rail tracks where there is no resultant risk of fire hazard. Flooding and mulching with a layer of straw, saw dust, woodchips, aluminium foil or plastic films are other methods of controlling grasses[19].

The above cultural, mechanical and physical methods of deweeding are invariably bound to be laborious, tedious, time-consuming and not very effective unless simultaneously chemical control is also resorted to. All over the world herbicides either alone or in combination with physical or mechanical methods, are used in both agricultural crop lands and non-agricultural lands for eliminating or controlling the undesirable grasses.

Herbicidal Control of Grass Weeds

Current chemical literature is copiously replete with the use of both inorganic and organic herbicidal chemicals which either kill the grasses or inhibit their growth. In the past decade many books on various aspects of weed biology, weed control and weedicides/herbicides their synthesis, physical and chemical properties have been published[2(b),12–16]. In a recent publication[15] the chemistry, degradation, mode of action, efficacy, persistence in soil, solubility, vaporisation, metabolism, reduction, oxidation, leaching, run off efficacy of various herbicides are very well documented.

Herbicides belong to two major categories, organic and inorganic. Compared to the organic herbicides inorganic herbicides are much less in number. Inorganic herbicides are limited to non-selective soil sterilants like borax, sodium chlorate, ammonium thiocyanate and arsenates. Majority of the herbicides are organic compounds and structurally these can be classified as follows : aliphatic chlorinated carboxylic acids—their salts and esters; aryloxyalkyl chlorinated carboxylic acids—their salts and esters; aromatic carboxylic acids and their derivatives; amides, anilides, symmetrical triazines, substituted ureas, derivatives of carbamic acid, derivatives of thio and dithio carbamic acids, substituted uracils, phenols and their esters, diphenyl ethers, amitrole type compounds, amines and anilines, carbanilates, organo arsenicals, picloram and related compounds, bipyridilium salts and naptalam, maleic hydrazide, pyrazon etc.

Based on the method of application, a herbicide can be either a contact herbicide or a translo-

cated systemic type, applied either on the foliage or to the roots. Besides, the herbicide can be specific and selective for a certain grass without affecting the desirable neighbouring crop or it can be a non-specific non-selective general herbicide killing not only the grass but also the surrounding vegetation. Depending on the time of application of the herbicide the following three types exist :

(*a*) prior to planting the crop

(*b*) after planting the crop and before *emergence* of the grass (Pre-emergence)

(*c*) after planting the crop and after *emergence* of the grass (Post-emergence).

The possible permutation and combination can thus lead to ($3\times2\times2=12$) twelve categories of herbicides e.g., non-selective contact herbicide like soil sterilants or a selective translocated foliage type for a perennial grass.

Contact herbicides kill the tissues at or very close to the point of application (roots or leaves). Foliar applied ones must be thoroughly distributed over the surface of the grass weed in order to kill the meristematic tissues in the buds and leaves. Selectivity for the specific grass depends on differential wetting, differences in cuticle, leaf arrangement as well as location of buds. Non-selective contact herbicides kill all vegetation including grasses. However, grasses having their growing points submerged below the soil are more resistant than other weeds having their buds exposed at the ends of the branches. Translocated systemic herbicides enter through the plant and move in the vascular tissues throughout the plant system. In this case selectivity is not based on morphological characteristics but on the biochemical nature of protoplasmic difference in enzyme systems etc. Rate of penetration, dosage and movement are to be so regulated that adequate herbicide is moved in without damaging the conducting cells or tissues. Sufficient concentration of the herbicide, should also reach the root or underground system to bring about the death of all cells capable of producing shoot buds.

N'-(3, 4-dichlorophenyl) -*N*, *N'*-dimethyl urea (DIURON), trichloro-acetic-acid, 6-chloro-*N*, *N*-di ethyl 1, 3, 5-triazine-2, 4-diamine (SIMAZINE) and 2, 4-dichloro-1-(4-nitrophenoxy) benzene (NITROFEN) are examples of pre-emergence herbicides.

1, 1'-dimethyl-4, 4'-bipyridinium dichloride (PARAQUAT), *N*-(3, 4-dichlorophenyl) propanamide (PROPANIL) and sodium 2, 2-dichloropropionate (DALAPON) are examples of post-emergence herbicides.

Penta-chlorophenol, *N'*-(3, 4-dichlorophenyl)-*N*, *N'*-dimethyl urea (DIURON), *N*-(3, 4-dichlorophenyl)-*N*-methoxy-*N'*-methyl urea (LINURON), trichloroacetic acid, 2, 4-dichlorophenoxy acetic acid (2, 4-D) and 6-chloro-*N*-ethyl-*N'*-(1-methyl-ethyl)-1, 3, 5-triazine-2, 4-diamine (ATRAZINE) can be either post-emergence or pre-emergence types of herbicides. Simazine is a non-selective herbicide for all grasses. A list of the herbicides and their formulations registered up to 9 Feb '79 in our country under the Insecticides Act 1968 are given in Table 1.

TABLE 1

LIST OF THE HERBICIDAL CHEMICALS AND THEIR FORMULATIONS REGISTERED UNDER INSECTICIDES ACT, 1968 UPTO FEB., 1979*

Chemical nomenclature of the herbicide (Common name)	Minimum percentage of technical grade	Active ingredient W/W				
		DP	WP	EC	Gr	Other formulations
2—chloro—2', 6'—diethyl—N—methoxy methyl acetanilide (ALACHLOR)	90	—	—	50	10	—
β—chloro—N—ethyl—N'—(1—methyl ethyl)— 1, 3, 5—triazine—2, 4—diamine (ATRAZINE)	80	—	50	—	—	—

Chemical nomenclature of the herbicide (Common name)	Minimum percentage of technical grade	Active ingredient W/W				
		DP	WP	EC	Gr	Other formulations
N—(butoxy methyl)—2—chloro—2′, 6′—diethyl acetanilide (BUTACHLOR)	85	—	—	50	5	—
N—(3, 4′—dichlorophenyl)—N, N′—dimethyl urea (DIURON)	95	—	80	—	—	—
2, 4—dichlorophenoxy acetic acid (2, 4—D)	97	—	—	→	—	58, 72 (Amino salt) 18, 34 (Ethyl Ester) 80, 85 (Na salt)
Sodium 2, 2—dichloropropionate (DALAPON)	95	—	—	—	—	—
N′—(3, 4—dichlorophenyl)—N—methoxy—N—methyl urea (LINURON)	*	—	50*	—	—	40 (Amino salt)
4—chloro—2—methyl phenoxy acetic acid (MCPA)	95	—	—	—	—	34 (Sol)
Mono sodium methanearsonate (MSMA)	*	—	—	—	—	—
N—2—benzothiazolyl—N N′ — dimethyl urea (METHABENZTHIAZURON)	92	—	72	—	—	—
2, 4—dichloro —1—(4—nitrophenoxy) benzene (NITROFEN)	86	—	—	25	8	—
1, 1′ —dimethyl—4, 4′ — bipyridinium dichloride (PARAQUAT)	40	—	—	—	—	24 (WSC) dichloride
PARAQUAT dimethyl sulphate	—	—	—	—	—	24 (WSC) dimethyl sulphate
N′ — (3 — chloro—4—methoxy phenyl) — N, N — dimethyl urea (METOXURON)	—	—	80	—	—	—
N — (phosphono methyl) glycine (GLYPHOSATE)	—	—	—	—	—	41 Solution
Penta chlorophenol (PCP)	96	—	—	—	—	12.5
N — (3, 4 — dichlorophenyl) propanamide (PROPANIL)	88	—	—	35	—	—
6 — chloro — N, N′ — diethyl — 1, 3, 5 — triazine — 2, 4 — diamine (SIMAZINE)	80	—	50	—	—	—
Trichloro acetic acid (TCA)	*	—	—	—	—	—
S — (2, 3, 3, — trichloro — 2— propenyl) bis (1 — methyl ethyl) carbamothioate (TRIALLATE)	20	—	—	50	—	—

*FLUCHLORALIN and SIRMATE (DICHLORMATE) also are in this list.

Indigenous Sources and Production of Herbicides

National Research and Development Corporation, New Delhi, have released the know-how for the manufacture of Simazine, Nitrofen and Dalapon through National Chemical Laboratory, Pune; and a broad spectrum weedicidal (herbicidal) formulation through Defence Materials and Stores Research & Development Establishment, Kanpur.

National Organic Chemical Industries Ltd., Bombay market herbicidal formulations for pre- and post-emergence control of grass in field and plantation crops e.g., 4-(methyl sulphonyl)-2, 6-dinitro-*N*, *N*-dipropyl aniline (PLANAVIN) and 2-<(4-chloro-6 (ethyl amino)-1, 3, 5-triazine-2-yl) amino>-2-methyl propane nitrile (CYANAZINE, BLADEX).

Agromore Ltd., Bangalore market weed killing formulations based on 2, 4-dichlorophenoxy acetic acid/ester/salts (WEEDONE/WEEDAR) and *N'*-(3, 4-dichlorophenyl)-N, *N'*-dimethyl urea (DIURON KARMEX) for the control of grasses in some field and plantation crops. Atul Ltd., Vadodara market 2, 4-dichlorophenoxy acetic acid esters/salts.

The consumption of 2, 4-dichlorophenoxy acetic acid/esters/salts was 202 tonnes and other weedicides were 96 tonnes in 1975-76. Forecast estimates for the years 1982-83 were given[17] in the following decreasing order : Nitrofen, Propanil, Butachlor. [*N*-(butoxymethyl)-2-chloro-2', 6'-diethyl acetanilide], Alachlor (2-chloro-2', 6'-diethyl-*N*-methoxymethyl acetanilide), MSMA (monosodium methyl arsonic acid), Dalapon.

Three units in our country produce 2, 4-dichlorophenoxy acetic acid/esters/salts with an installed capacity of 1935 tonnes. One unit produces *N*-(3, 4-dichlorophenyl) propanamide (STAM) and 2, 4-dichloro-1-(4-nitro)-phenoxy benzene (TOK) with a rated capacity of 1500 tonnes.

Herbicidal Application for the Control of Grasses

The application of herbicidal chemcials is enumerated hereunder for the control of grasses. The discussion is limited to only such herbicides (Table 1) which are registered up to February 1979 in our country under the Insecticides Act 1968. A brief mention of the use of maleic hydrazide is also made.

Sodium 2,-2-dichloropropionate (*DALAPON*). The sodium salt of 2, 2-dichloropropionic acid is highly water soluble (m.p. 174-176°C dec.; LD50 6000—8000 mg per Kg).

This is a contact herbicide for monocotyledonous weeds like grasses. The trade names are 'DOWPON' 'RADAPON' for products of Dow and BASFAPON for products marketed by BASF. Dalapon is a growth regulator and is translocated in plants producing systemic growth aberrations. This is absorbed by roots as well as foliage. This has the same effect like trichloro acetic acid (TCA) on grass plants viz., fusion, buckling or tubular leaf formation, stunting, excessive tillering and with appropriate dosage slow death. This can be applied as an aqueous solution directly on foliage or to roots through the soil. When applying this chemical to the soil, a surfactant or wetting agent is necessary to ensure proper wetting of the leaves. Being phloem mobile, dalapon is useful in the control of perennial grasses (dosage 12-40 Kg/ha) in the same way as 2, 4-D is useful for controlling broad leaved weeds. Dalapon has found world wide use and acceptance in that it is used, either alone or with other herbicides, in large quantities wherever and whenever grasses pose a serious problem as weeds. Dalapon[45] (40 Kg/ha) controls *Cynodon dactylon* (Bermuda grass) and *Imperata cylindrica*[46] (African spear grass) in rubber plantations.

Dalapon and 2, 4-D with a wetting agent is recommended for the control of mixed populations of annual grasses and broad leaved weeds[13(a)]. Other grasses controlled by dalapon are [13(a)], (Kikuyu grass) annual grasses in alfalfa seedling or established, *Cynodon dactylon* (Bermuda grass) and *Sorghum halepense* (Johnson grass) in asparagus cutting beds, *Echinochloa crusgalli* (water grass) in sugar beets, *Agropyron repens* (quack grass) in corn, perennial grasses in sugarcane, *Poa annua* and *Cynodon dactylon* (Bermuda grass) in dichondra, *Sorghum halepense* (Johnson grass) or *Cynodon dactylon* (Bermuda grass) in grapes, red clover, almonds, apricots, peaches and plums, undesired grasses in pastures and turfs, *Digitaria spp.* (crab grasses) in subtropical turf grasses, *Cynodon dactylon* (Bermuda grass) and *Paspalum dilatatum* (Dallis grass) in turf grasses of temperate zones.

Dalapon is reported to be more effective[14] than TCA in the control of *Agropyron repens* (quack or couch grass). Both these herbicides are recommended[13] as non-agricultural soil sterilants for controlling *Agropyron repens* (quack grass) in small areas and non-crop lands. Subsequent application is necessary in case of resprouting.

Dalapon and TCA are the possible choices for controlling *Agropyron repens* (quack grass) in extensive areas of cultivated land by applying early in the season after allowing the plants to stand for two weeks and then ploughing[13]. It can then be followed by a late planted crop particularly a smother crop resistant to the particular herbicidal chemical. A second treatment in the subsequent year may be necessary. Application in the fall can be accompanied by normal cropping in the spring. *Cynodon dactylon* (Bermuda grass) and (Bahama grass) are better controlled by dalapon than TCA salts[14]. Two or three smaller doses of application are better than one larger heavy dose. The use of dalapon in combination with ploughing is reported effective in controlling *Cynodon dactylon* (Bermuda grass) in Dharwar (Karnataka)[24]. Application of paraquat three or four weeks after applying dalapon twice is reported to be very effective in controlling *Cynodon dactylon*[25] (Bermuda grass). Mixed application of dalapon and paraquat controlled rank grasses including *Digitaria spp* (crab grasses), *Panicum spp* (Guinea grass)[25], *Eleusine spp* (goose grasses)[40]. Dalapon is reported to control perennial grasses like *Sorghum halepense* (Johnson grass) *Cynodon dactylon* (Bermuda grass) and *Agropyron repens* (quack grass) in cotton fields[14]. Dalapon with paraquat controlled *Sceleria bractacus* (razor grass)[47], *Dactylis glomerata* (orchard grass), *Poa pratensis* (Kentucky blue grass). Mixtures of dalapon and sesone for general weed killing and dalapon and silvex for the control of *Pennisetum clandestinum* (kikuyu grass) are reported[13(a)]. Dalapon has been used for the control of grasses in alfalfa[57], lucerne[57], asparagus[14], beets[14], potatoes, peas and sweet potatoes[14], fruit crops and orchards[80], American sycamore and gladiolus[71], cocoa/coffee/tea/rubber plantations[73].

Trichloroacetic acid (*TCA*). TCA has a m.p. 57.3° C, and b.p. 195°C at 760 mm of mercury. This herbicide is marketed under the trade name, NATA or NATAL (Farbwerke Hoeehst) and TECANE. This is a protein precipitant and hence an active killing agent. This chemical is an effective grass killer and used at a dosage of 5-20 Kg/ha. Its sodium and ammonium salts are being produced commercially and are excellent reagents for the control of perennial grasses[13(a)] e.g., *Sorghum halepense* (Johnson grass) in sugarcane. For killing *Sorghum halepense* (Johnson grass) and *Cynodon dactylon* (Bermuda grass) the required rates are around 90 to 112 Kg/ha. For handling *Echinochloa crusgalli* (water grass)and *Digitaria spp* (crab grasses) seedlings in cotton and sugar beets, dosage as low as 5.5 Kg/ha have proved effective in the form of aqueous sprays and ensuring contact with roots for controlling perennial grasses.

TCA application must be timed for optimum absorption by roots. In regions of frozen soils application in the spring just after the soil thaws is effective. In regions of frequent rainfall early fall or early spring applications present the chemical in the root zone before the soil temperature becomes sufficiently elevated to promote any rapid break down. In regions of winter rains and dry summers winter or spring applications are favourable. Less rainfall is required to carry the chemical to the roots in sandy soils than in clay soils. Mid-summer application even in regions of summer rains is not effective because TCA is subject to rapid breakdown in warm moist soils.

Being a strong acid it is too corrosive to be phloem mobile, possibly it serves as a growth regulating factor lacking the stimulating action of an auxin.

Sodium TCA is more effective than the ammonium salt. It is rapidly soluble in water and the solution is nearly neutral so that there is no corrosion of the spray equipment.

Sodium TCA leaches freely in the soil and is absorbed by the roots of grasses quite readily *Sorghum halepense* (Johnson grass), *Cynodon dactylon* (Bermuda grass) and *Agropyron repens* (quack grass) have responded to applications ranging from 112 to 224 Kg/ha. However, where grasses are treated beneath the trees and vines, injury to the trees and vines often occurs, indicating that the herbicide has a limited usefulness only in this selective manner.

Sodium TCA gives selective control [13(a)] of annual grasses *Cardaria diaba* (crested wheat grass), *Setaria spp* (foxtails) and *Avena fatua* (wild oats) in certain crops (sugar beets, onions, alfalfa, sweet clover and barley) without injury to the crops on Fort collins loam, a medium textured soil high in organic matter nitrate and phosphate.

In controlling perennial grasses [15(a)] it has been found that ploughing or cultivating the land either just before or sometime soon after application of TCA greatly improves the results. Apparently the tillage weakens the grass plants exposes the rhizomes and roots to the chemical and brings about a more thorough mixing of the chemical with the soil.

TCA is useful against annual grasses [13(a)] as well as perennial species and is used as a grass killer in cotton, sugar beets and spinach. TCA controls grasses in : barley, rye and oats[54], flax[14], peas[14], alfalfa and lucerne[5], beets[14], cole crops[14], TCA controls quack grass[14], and applied[14] as a soil sterilant (56.5—113.5 gm/sq rod, with a subsequent application in case of resprouting) for small areas and non-agricultural non-crop lands. Two sprays of sodium salt of TCA (20 Kg/ha) controlled *Elytrigia repens* (couch grass) to an extent of 98.2%.

For extensive areas in cultivated land TCA is a possible choice for application early in the season after allowing the plants to stand for 2 weeks and then ploughing[13], followed by a late planted crop particularly a smother crop resistant to TCA. In the subsequent year a second treatment may be necessary. TCA salts[14] (temporary soil sterilants 36.73—45.35 Kg/acre controls *Cynodon dactylon* (Bermuda grass) and (Bahama grass) confined to small patches and for controlling seedling grasses (2.27—4.54 Kg/acre) sugar beets, red beets, sugarcane and cabbage.

TCA at 90.70 Kg/acre is effective [29,50] for post surface treatment [29] after a pre-surface treatment in the spring (just before the prime coat) for control of *Cynodon dactylon* (Bermuda grass) in asphalt surfaces on shoulders especially those along the inside of divided highways and on roads with low load traffic as also Central islands and reservations paved with asphalt and used for channelisation. The pre-surface treatment is followed by subsequent treatments after 30 days when the plants become green again.

2,4-*dichlorophenoxy acetic acid* (2, 4-*D*). 2, 4-D is a white crystalline substance, m.p. 141° C and has no odour when pure. A systemic herbicide this chemical is marketed, under various trade names like CHLOROXINE WEEDAR WEEDONE and SALVO. No other herbicide is of as wide application as 2, 4-D for controlling weeds. This has the properties of a plant hormone. Literature is full of publications pertaining to the use of 2, 4-D esters amines and salts mainly for the control of broad-leaved annuals, however, 2, 4-D in combination with dalapon and a wetting agent can be used as a foliar spray to control mixed populations of annual grasses and broad leaved weeds as well[13(a)].

2, 4-D ester or amine were used for controlling grasses in the following agronomic crops[14,63,66,73] peas, sorghum, flax, alfalfa, lucerne, peas, fruit crops and orchards, sugarcane, cocoa, coffee, tea and rubber plantations.

This chemical in combination with atrazine or organo arsenicals like MSMA controls *Sporobolus poiretti* (smut grass)[49]. 2, 4-D amine or acid applied in early spring and repeated for two or three months gave a good performance in pre-emergence control of grasses in lawns and turf[14]. 2, 4-D controls[56] effectively *Imperata cylindrica* (African spear grass).

4-*chloro*-2-*methyl phenoxy acetic acid* (*MCPA*). MCPA is a white crystalline substance, m.p. 120°C—120·2°C. This herbicide is marketed under the trade names AGROXONE AGRITOX (May and Baker) CORNOX-M (Boots) MEPHANEL METHOXONE and WEEDAP. With 2, 3, 6-TBA this chemical has been used for the control of *Galium spp* (bedstraw) in wheat[13(a)]. Although grasses in pea[14] are controlled by this chemical, like 2, 4-D. This is more useful in controlling[13 (a)] annual broad weeds in flax, grain sorghum, ladinoclover, forage, pasture, oats and rice.

N-(3, 4-*dichlorophenyl*) *propanamide* (*PROPANIL*). This is a white crystalline substance, m.p. 91°-92° C. Bayer market this chemical under their trade names SURCOPUR and Rohm and Haes sell this is STAM F 34. Like dalapon and paraquat this is a post-emergence herbicide. Propanil is reported[37] to control, at a dosage of 6.75 Kg/ha, tillering and jointing of the annual *Echinochloa crusgalli* (barnyard grass) in rice fields. The control of this grass in rice is one of

the most challenging problems in selective weed control. Rice sprayed at 1.12, 2.24 and 4.48 Kg/ha had 74, 80 and 90% control of *Echinochloa crusgalli* (barnyard grass) and yielded 56—90 and 88 bu/acre whereas unsprayed rice yielded 18 bu per acre [13(a)]. Because of its action on crowns and roots of the weeds it is assumed that this herbicide is translocated.

2-chloro-2', 6'-diethyl-N-methoxy methyl acetamide (*ALACHLOR*). This chemical is a pre-emergence herbicide marketed under the trade names CP 50144 and LASSO by Monsanto. It controls *Digitaria spp* (crab grasses) in cultivated fields[32,55]. *Eleusine indica* (goose grass) is reported[40] to be controlled, by this chemical, in container grown azales and ivy. Alongwith chlorobromuron, alachlor controls[41,52,80] *Setaria viridis* (green foxtail) in soybeans. It also controls grasses in vegetable crops like potatoes and sweet potatoes[61], and in American, sycamore and gladiolus[70]. with dalapon and paraquat, alachlor controls[48] *Phalaris arundanacea* (reed canary grass).

N (butoxy methyl)-2-chloro-2', 6'-diethyl acetamide (*BUTACHLOR*). This is a pre-emergence herbicide like alachlor. MACHETE (Monsanto) is a trade name for this chemical. Butachlor controls undesired grasses in rice and wheat[7] and *Cynodon dactylon* (Bermuda grass) weed flora in agricultural crop land in Haryana and in rice fields in Kerala[9]. It also controls *Echinochloa crusgalli* (barnyard grass) weed flora in agricultural crop lands of Haryana[38].

6-chloro-N-ethyl-N'-(1-methyl ethyl)-1, 3, 5-triazine-2, 4-diamine (*ATRAZINE*). Atrazine is a white crystalline substance, m.p. 173°—175° C.

This chemical is marketed by Ciba-Geigy under the trade names G-30027, GESAPRIM and PRIMATOL. Being somewhat more soluble than simazine, this chemical kills very small weeds by contact action and, therefore, this can be used not only as a post-emergence but also as a pre-emergence herbicide. Because of its greater solubility it is more effective than simazine under conditions of low rainfall (7.5—12.5 cm) in controlling annual grasses and broad leaved weeds[13(a)].

As a symmetrical triazine herbicide, this chemical can be used for eliminating grasses on roadsides, fence lines, ditch banks and many other places.

Atrazine is used for eliminating grasses in corn[15,14], maize[31,33], fruit crops and orchards[14] and nursery beds[13,75] besides American sycamore and gladiolus[71].

Atrazine (2.72 Kg/acre) controls *Agropyron repens* (quack grass) and *Agropyron riparium* (couch grass) which are serious weeds in many parts of the world and spread by means of abundant seeds and rhizome[13]. The chemical is applied at such a controlled rate not to kill the weed but to inhibit it temporarily and the crop (corn) is harvested by the time the weed recovers[13]. Atrazine controls summer annuals like *Digitaria spp* (crab grasses) in cultivated crop fields[32]. A liquid formulation of atrazine as a suspension in a penetrant non-phytotoxic emulsifiable paraffin oil is found[33] more effective in controlling *Digitaria spp* (crab grasses) than the same chemical used as a wettable powder. A similar finding was reported for this chemical in the control of *Echinochloa crusgalli* (barnyard grass) a common weed in rice fields[36], maize fields[33] and for controlling *Setaria spp*[33].

6-chloro-N, N'-diethyl-1, 3, 5-triazine-2, 4-diamine (*SIMAZINE*). Simazine is a white crystalline substance, m.p. 227°—228° C.

Ciba-Geigy market this non-selective herbicidal chemical for all grasses under the trade names of GESATOP, PRINCEP and PRIMATOL. Being a chloro substituted triazine it has lack of phloem mobility to soil application. Like the substituted areas these are readily absorbed by roots and translocated in the transpiration stream. Like substituted ureas this inhibits the Hill's reaction *i.e.*, blocking the release of oxygen from water in the presence of chloroplast, light and a suitable *H*-acceptor compound.

Simazine is used for controlling annual weeds in crops[13(a)], and for mixed populations of annual grasses and broad leaved weeds preferably before weeds have emerged. Simazine has been used with success in controlling grasses in : field crops grown in rows (corn[51], soyabeans[41]); vegetable crops (asparagus)[14]; fruit crops and orchards [79]; sugarcane[67]; American sycamore and gladiolus[71]; cocoa, coffee, tea, and rubber plantations[73] and nursery beds [13,75].

Simazine (2.72 Kg/acre)[13] completely eliminates *Agropyron repens* (quack grass) and *Agropyron riparium* (couch grass). Lower doses at the

same time give adequate control. No damage is caused to conifers or ornamentals. Simazine (10.89 Kg/acre)[19] applied in the spring when *Agropyron repens* (quack grass) is about 18 cm tall gives the best control but proves phytotoxic to the subsequent crops. *Panicum colonum* (Jangli madira grass) is controlled by simazine (0.3—0.9 Kg/donum=[illegible] m^2). Simazine (3.4 Kg/ha) controls *Setaria viridis* (green foxtail) in soyabeans.

Common *Cynodon dactylon* (Bermuda grass), a turf grass is especially tolerant of simazine whereas other lawn grasses like *Cynodon spp* (African Bermuda grass) and *Poa spp* (blue grass) are easily injured by simazine. Simazine provides a good pre-emergence control[14] over *Eremochloa ophiuroides* (centipede grass) and *Axonopnes spp* (carpet grass) at 0.45 Kg/acre for sandy soils and 1.81 Kg/acre for heavy soils with organic matter. Simazine (0.45 Kg/acre) applied in early spring and repeated after 2-3 months gives a good pre-emergence control of grass weeds in lawns and turf.

2, 4-*dichloro*-1-(4-*nitrophenoxy*) *benzene* (*NITROFEN*). It is a pale yellow crystalline substance, m.p. 70°-71°C.

Röhm and Haas market this chemical as 'FW 925' and TOKE E-25. The other trade names for this chemical are NIP NICLOFEN. This is a pre-emergence herbicide and has been used for controlling *Cynodon dactylon* (Bermuda grass) and *Echinochloa crusgalli* (barnyard grass) in agricultural croplands in Haryana[9,38]. Nitrofen (1.3—61.81 Kg/acre) effectively controls *Lolium multiflorum* (annual rye grass) in wheat and increasing its yield by 20%. Nitrofen (1.36—1.81 Kg/acre) has been used[22] for controlling *Avena fatua* (wild oats) in winter wheat. Grasses in the following are controlled by this chemical : rice and wheat[9], barley, rye and oats[22], and Japanese mint[65]. 2.56 million hectacres (96% of the cultivated fields) in Japan [15] are treated with this pre-emergence herbicide.

N-(*phosphonomethyl*) *glycine* (*GLYPHOSATE*). This is marketed by Monsanto under their trade name ROUND UP. This post-emergence herbicide controls grasses in cucur-bits[59], fruit crops and orchards[30,79], ornamentals [20,68], American sycamore and gladiolus[70], cocoa, coffee, tea, rubber and forest plantations[73]. *Panicum repens* (torpedo grass) in tea plantations in Ceylon[39], *Digitaria scelarum* (African couch grass) in coffee plantations[34] and grasses in forest plantations in papua New Guinea[28] are reported to be controlled by glyphosate. Application of glyphosate (10.89 Kg/acre) in the spring to *Agropyron repens* (quack grass) when it is about 18 cm tall gives the best control but is phytotoxic to subsequent crops[18,78]. Green house studies show that *Cynodon dactylon* (Bermuda grass) is controlled by glyphosate (0.84-1.12 Kg/ha).

N-(3, 4-*dichlorophenyl*)-*N*, *N'*-*dimethyl urea* (*DIURON*). Diuron is a white crystalline substance, m.p. 158°-159°C.

KARMEX (DUPONT) is its trade name as also MARMEX. Diuron is recommended for industrial and agricultural soil sterilisation in regions of medium to high rainfall [13(a)]. It is finding extensive application as a pre-emergence herbicide for cotton at dosages of 1-2 Kg/ha and certain vegetable crops. Diuron has been thoroughly tested for use in crops and has proved safe in cotton, alfalfa, sugarcane, grass seed, peppermint, cranberries, olives and vacent lots[13(a)]. Diuron controls *Digitaria spp* (crab grasses) in cultivated crop fields[32]. Diuron with simazine controls *Panicum colonum* (Jangli Madira grass). Diuron has been successfully used in weeding out grasses in sugarcane[66], fruit crops and orchards[14] and coffee or tea plantations[72,73].

N-(3, 4-*dichlorophenyl*)-*N*-*methoxy*-*N*-*methyl urea* (*LINURON*). Linuron is a white crystalline substance, m.p. 93°-94°C.

LOROX (DUPONT) and ATALON (Farhwerke Hoechst AG) are the trade names. With this herbicide grasses in corn, soyabeans, cotton, potatoes and sweet potatoes are reported to be controlled.

N'-(3-*chloro*-4-*methoxyyphenyl*)-*N*, *N*-*dimethyl urea* (*METOXURON*). DOSANEX (SANDOZ) is its trade name. Like diuron and linuron this is an asymmetric substituted phenyl urea type herbicide absorbed from the soil and translocated into the top via the transpiration system for control of grasses in certain vegetable crops.

N-2-benzothiazolyl-N, N'-dimethyl urea (*METHA BENZ THIAZURON*). TRIBUNIL (BAYER) is its trade name. This belongs to the same category of herbicides as diuron, linuron and metoxuron. At low dosages it is selective in controlling seedling growth of grasses in certain crops. At higher dosages it can be used as a soil sterilant in non-agricultural areas.

1, 1'-*dimethyl*-4, 4'-*bipyridinium* (*dichloride or dimethyl sulphate*) (*PARAQUAT*). Paraquat dichloride, a quarternary ammonium salt, is non-volatile and extremely soluble in water.

DEXTRONE GRAMOXONE and WEEDOL are trade names for this chemical. The dimethyl sulphate (or the paraquat) is a general contact spray[13(a)]. The dichloride at dosages of 0.6 to 1 Kg/ha controls grasses in : rice and wheat[9], curcurbits[59], fruit crops and orchards[38,80], citrus orchards in Cyprus[25], white clover[2,16,4], and sugarcane[66]. It is also recommended for general grass control[76] and for controlling *Imperata cylindrica* (African spear grass)[46], *Scelaria bractacus* (razor grass)[47], *Eleusine indica* (goose grass)[25], *Panicum maximum*[25] (guinea grass), *Cynodon dactylon* (Bermuda grass) in Dharwar Karnataka[24,25,26]. This group of herbicides have relatively high toxicity to animals which ranges within the limits 30—70 mg/Kg as the ration.

Monosodium methane arsonate (*MSMA*). This organo arsenical herbicide is marketed under the following trade names : ANSAR BUENO DACONATE PHYBAN SILVISAR and WEED-E-RAD.

This has been recommended[77] for general grass control. MSMA has been used for eradicating grasses in cocoa, coffee, tea, rubber, and forest plantations[74]. This chemical (0.0—1.46 Kg/acre) gives good control [15,23,42,43], of :—

Andropogon annulatus (angelton grass), *Echinochloa crusgalli* (barnyard grass), *Sporobolus indicus* (black seed grass), *Bromus secalinus* (cheat grass), *Pennisetum ciliare* (buffel grass), *Digitaria spp* (crab grasses), *Paspalum conjugatum* (dallis grass), *Sorghum halepense* (Johnson grass), *Pennisetum clandestinum* (kikuyu grass), *Avena fatua* (wild oats), *Rottboellia exaltata* (Raoul grass), *Echinochloa colonum* (jungle grass), *Stenotaphrum secundatum* (St. Augustine grass), *Distichlis stricta* (salt grass, desert), *Brachiaria platyphylla* (signal grass, broad leaf), *Sporobolus poiretti* (smut grass), *Chloris divaricata* (star grass Australian), *Echinochloa crusgalli* (water grass), *Andropogon nodosus* (wild grass), *Panicum capillare* (witch grass) and *Imperata cylindrica*[56] (African spear grass).

Penta chlorophenol (PCP). Penta chlorophenol has a m.p. 190°-191°C, b.p. 310°C, at 760 mm of mercury. This is not only an insecticide and a fungicide but also a herbicide. The trade names are DOWICIDE (DOWCHEMICA) SANTOBRITE and SANTOPHEN 20 (MONSANTO) CHLOROPHEN, GLAZD PENTA and SINITUHO.

In weeding out *Panicum capillare* (witch grass) in soybean fields pre-emergence use of PCP at 2.24 Kg/ha with rotary hoeing gave superior results[13(a)]. PCP controls *Echinochloa crusgalli* (barnyard grass) in transplanted rice plants[15], and grasses in soybeans and peanuts[14]. PCP and its sodium salt, however, finds more use in removing weeds other than grasses and is the most available and cheapest material for fertifying oil emulsion for deweeding.

3-*Hydroxy Pyridazone* (*Maleic Hydrazide; MH*). Maleic hydrazide is a white crystalline substance dec. temperature 300°—320°C. 'SLOGRO' 'SUCKER STUFF' 'SUPER SUCKER STUFF' 'RETARD' 'DESPROUT' 'MALAZIDE' and 'REGULOX' are its trade names. This is a growth inhibitor and grass killer[13(a)]. As a growth inhibitor it controls the blosoming of certain horticultural crops for holding back growth on hedges, lawns etc. As a grass killer it is effective against all species tested so far but appears most promising for controlling perennials like *Agropyron repens* (quack grass), *Cynodon dactylon* (Bermuda grass) or *Sorghum halepense* (Johnson grass)[13(a)]. Spraying with 10 per cent MH, followed after a week with turning of the sod by ploughing, has proved very effective in the control of *Agropyron repens* (quack grass). MH controls perennial grasses in corn but broad leaved annual weeds are not affected. The annuals are eliminated by using a pre-emergence material alongwith MH and also by contact spraying on foliage or tillage or both.

Pennisetum purpureum (Napier grass or elephant grass) is a perenicious perennial weed of extensive wild and rapid growth in North-Eastern sector of Assam and Meghalaya, presenting a serious problem to the Army and Air force units located there. Defence scientists at Defence Science Laboratory, Delhi, report sodium chloride (250 Kg/ha) to be phytocidal to young plants of this weed whereas MH (50 Kg/ha) is found to be permanently suppressing growth of older plants of height not less than 1 metre and killing the leaves of young plants not exceeding 0.5 m height[3].

S-(2, 3, 3,-*trichloro*-2-*propenyl*) *bis* (1-*methyl*-*ethyl*) *carbamothioate* (*TRIALLATE*). Triallate is a clear liquid, b.p. 165°C at 6 mm of Hg. AVADEX BW and FARGO are the trade names for this herbicide reported[55] to control weeds in flax, wheat, barley, beets and peas at dosages from 1 to 1.5 Kg/ha.

CONCLUSION

There exists ample scope for application of various herbicidal chemicals either alone or in combination, for selective control through foliage contact or translocation or non-selective control through foliage/roots/translocation, in controlling and containing the problem of undesired grasses encountered by the three Defence Services Inter Service Organisations and military farms.

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