Translated from *Uspekhi Khimii*, **45**, 1473 - 1504 (1976) U.D.C. 632.95 : 54 : 66

Synthetic Plant Growth Regulators and Herbicides

N.N.Mel'nikov

The literature on the principal applications of various classes of inorganic and organic compounds as plant growth regulators and as agents for the suppression of weeds is briefly reviewed. The most important classes of chemical compounds employed for such purposes are quoted.
The bibliography includes 492 references.

CONTENTS

I.	Introduction	744
II.	Inorganic compounds	746
III.	Alcohols, phenols, and ethers	746
IV.	Amines and quaternary ammonium salts	746
V.	Carboxylic acids and their derivatives	747
VI.	Carbamic and thiocarbamic acid derivatives	749
VII.	Urea and thiourea derivatives	750
VIII.	Organophosphorus and organoarsenic compounds	751
IX.	Heterocyclic compounds of different series	753

I. INTRODUCTION

The first studies on the synthesis of plant growth regulators in the Soviet Union were carried out by Nametkin as early as 1938.[1] He is justly regarded as a pioneer in this field, which is important for the national economy. Subsequent studies on these lines were continued in the laboratory organised by Nametkin at the Timiryazev Institute of Plant Physiology of the USSR Academy of Sciences; the results of this research led to the beginning of the manufacture in the USSR of preparations such as heteroauxin, 1-naphthylacetic acid, its potassium salt and methyl ether, magnesium chlorate (a defoliant), the butyl ether of 2,4-D, and certain others[2,3].

Plant growth regulators and herbicides have now found practical applications in the following principal fields[4]:

In the fight against weeds infesting a wide variety of agricultural crops, in meadows, pastures, and in forests and against undesirable plants on highways, in airports, on industrial sites, in water reservoirs, etc.[5]

In the removal of leaves prior to the harvest in order to mechanise the harvesting of the crop or in the transplanting of fruit and decorative plants and of the grapevine in order to enhance their frost resistance and increase the yield from the initial planting.

In the desiccation of plants to achieve partial drying and mechanisation of the harvesting of potatoes, rice, soya beans, and various other crops; desiccation by chemical preparations in many cases replaces the partial drying of feed crops prior to harvesting.

In the fight against the flattening of wheat, rice and other crops under conditions of increased humidity.

To increase the harvest of soya beans, peas, leguminous plants, and cotton seeds.

To increase the size of plums, pineapples, and other fruit.

To stimulate plant growth by the treatment of seeds of various crops prior to planting.[6]

To suppress the growth of young shoots to increase the intensity of flowering and fruiting of apples, pears, strawberries, and many other crops.

In the prevention of the shedding of apples and pears prior to harvesting and for the improvement of their commercial qualities and colour.

In the reduction of the strength of attachment of fruit to the stem (tomatoes, citrus fruit, etc.) for the purpose of mechanisation and in order to facilitate harvesting.

In the regulation of the metabolism of the cotton plant in order to enhance and accelerate the growth of its crop.

To increase the content of latex in rubber producing plants and to increase the content of sugar in sugar cane and sugar beet.

To accelerate the ripening of peaches and cherries.

To increase the harvest and to obtain parthenocarpic (seedless) tomatoes and other crops.

To retard the growth of tobacco shoots (chemical sucker control).

In the prevention of the germination of potatoes, onions, sugar beet, etc. on prolonged storage.

For the stimulation of the rooting of plants in their vegetative propagation by cuttings.

For the termination of the state of rest of potato tubers in order to employ them as seeding material during harvest[7].

In the destruction of male plant pollen in the cultivation of the hybrid seeds of various crops (mainly cereals).[8]

To accelerate the ripening of a number of crops.

To stimulate the opening of appleblossom and the blossom of certain other cultivated plants.

To retard the growth of lawns in order to reduce the expense of cutting.

To increase the number of internodal sections and to intensify the flowering and growth of decorative plants (chrysanthemums, azaleas, peonies, lilies, etc.).

To increase the life of cut flowers.

To stimulate the rooting of trees after transplanting.

To protect plants from the harmful action of certain herbicides.

Certain other practical applications of plant growth regulators have been described, but the studies in this field are at present in their early stages and their usefulness is not, as yet, entirely clear.

The scale of the practical applications of synthetic plant growth regulators and herbicides and the prospects for their further utilisation can be assessed from the data in Table 1,[9] which presents information on the sale of such products in the world and in the USA, expressed in terms of the 1974 prices.

Table 1. The sale of herbicides and plant growth regulators in 1971–1980.

Preparation	In the USA, million dollars			Worldwide, million dollars		
	1971	1974	1980	1971	1974	1980
Herbicides	640	1058	1523	1131	2190	3422
Plant growth regulators	18	29	40	40	77	118
Defoliants and desiccants	8	18	23	12	19	31
Total	666	1105	1586	1183	2286	3571

Evidently, chemical agents for the suppression of weeds are employed on the largest scale, which is quite understandable, since their application permits a sharp increase of labour productivity in agriculture[10]. It is sufficient to point out that, solely as a result of the expanded use of herbicides in the USA, labour productivity in agriculture increased by almost 20% from 1970 to 1974.[10] The scale of the employment of herbicides for different crops can be inferred from the data in Table 2.[9]

Table 2. The consumption of herbicides in relation to various crops (in terms of 1974 prices, million dollars).

Crop	In the USA			Worldwide		
	1971	1974	1980	1971	1974	1980
Maize	242	423	574	353	680	1061
Cotton	110	97	140	170	240	420
Wheat	40	47	71	100	200	281
Sorghum	20	33	49	28	55	81
Rice	30	23	33	106	181	309
Other grain crops	10	15	24	28	54	80
Soya beans	100	286	432	144	410	584
Tobacco	—	6	9	—	11	18
Groundnuts	14	17	24	21	32	55
Sugar beet	9	11	15	44	81	132
Other field crops	10	16	23	28	52	81
Alfalfa	5	6	9	8	16	27
Other feed crops	5	5	9	8	13	21
Meadows and pastures	15	24	36	22	40	64
Orchard crops	30	49	75	71	125	208
Fruit crops	10	19	32	29	51	86
Vegetables and potatoes	20	30	43	42	74	122
Total	640	1058	1523	1131	2190	3422

Data concerning the application of different classes of herbicidal materials are presented in Table 3,[9] which shows that the increase of the consumption of different classes of chemicals as herbicides is not uniform; the greatest increase has been in the consumption of classes of compounds which satisfy most fully modern requirements as regards selectivity of action and their influence on various objects in the environment.

The increase in consumption is greatest for new preparations, which decompose fairly rapidly in the soil and in the plant and do not leave toxic residues in the crop being protected.

In connection with the necessity for the protection of the environment, there has been an increase in the stringency of the requirements which must be met by the preparations, which significantly increases the cost of their synthesis. Data on the screening and development of new pesticides by ICI,[11] which are listed in Table 4, are interesting in this respect. Whereas in 1956 one out of 1800 compounds synthesised was subsequently manufactured on an industrial scale, in 1972 not a single preparation of the 10 000 compounds tested was manufactured industrially. In connection with the large number of biological tests, the overall period from synthesis to practical introduction into an industrial manufacturing process and agriculture lasts between 7 and 9 years.[10,11]

Table 3. The consumption of individual classes of herbicides (in terms of 1974 prices, million dollars).

Class of compounds	In the USA			Worldwide	
	1971	1974	1980	1974	1980
Arsenic compounds	8.3	11	15	27	25
Aryloxyalkanecarboxylic acids	48.2	50	65	152	260
Urea derivatives*	72.5	70	91	173	313
Carbamates and thiocarbamates**	103.0	108	120	252	363
Triazines***	340.0	314	419	620	907
Benzoic acid derivatives****	72.0	100	115	140	213
Other classes*****	413.0	405	698	826	1341

Monuron, Diuron, Phenurone, Linuron, Cotoran, and Thenoran.

**IPC, Chloro-IPC, Ordram, Tillam, Darban*, Vegadex, Avadex, Ramrod, Propanide, and Azak.

***Atrazine, Simazine, Prometon, and Prometryn.

****Amiben, Banvel-D, trichlorobenzoic acid.

*****Treflan, Paraquat, dinitrophenols, Planavin, Dynap, Solan, Herban, Lasso, Pyramin, etc.

Table 4. Results of the screening and introduction of ICI pesticides.

Type of test	1956	1964	1967	1969	1970	1972
Number of compounds screened	1800	3600	5500	5040	8000	10 000
Compounds isolated on screening	60	36	—	126	80	—
Compounds subjected to field tests	6	4	—	9	4	—
Compounds subjected to further investigation	2	2	—	2	2	—
Compounds offered for sale	1	1	1	1	1	1

Despite the high cost and considerable difficulties in the utilisation and development of new preparations, intense research is being continued in this field and new interesting herbicides and plant growth regulators appear annually, which is associated not only with the possibility of a sharp increase in labour productivity in agriculture but also with the greater economic efficiency in consequence of the considerable increase in the harvest and the improvement of the quality of agricultural produce[12-14].

An enormous number of compounds of different classes with physiological activity in plants have now been described; approximately 200 substances have found

practical applications as plant growth regulators and herbicides[3-5]. Without concerning ourselves with the general theoretical problems of the nature of the action of various preparations, which have been described in fair detail in the Proceedings of the 7th International Congress[15] and in reviews and monographs[16-19], we shall consider the principal classes of chemical compounds which have found applications as plant growth regulators and herbicides in different branches of agriculture.

This review does not deal with cytokinins and gibberelins, which are described in a recent monograph in Russian.[20,21]

II. INORGANIC COMPOUNDS

Among inorganic compounds, chlorates have found fairly extensive applications as herbicides and defoliants. Potassium chlorate is used in the fight against weeds[5] and sodium, magnesium, and calcium chlorates are used to defoliate and desiccate the cotton plant and other crop plants for the purpose of the mechanisation of their harvesting[22]. In order to decrease the risk of explosion, sodium borate is added to sodium chlorate and magnesium chlorate is employed as an equilibrium mixture of sodium and magnesium chlorates and chlorides, obtained on treatment of sodium chlorate with magnesium chloride. Calcium chlorate is used as the mixture produced by treating lime with chlorine.

Among other inorganic compounds, copper compounds (nitrate and sulphate)[2,3] and ammonium sulphamate have found applications as algicides. However, the amount of ammonium sulphamate consumed per hectare is about 200 kg, which sharply reduces its use[2].

III. ALCOHOLS, PHENOLS, AND ETHERS

Allyl alcohol has found application as a herbicide[3]. C_6–C_{10} saturated alcohols are employed in sucker control for the tobacco plant[23]. Their use in combination with systematic plant growth regulators is particularly effective[24]. It is then possible to reduce the labour required for the cultivation of tobacco by more than 50%.

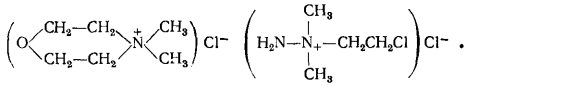
Methyl 1-naphthylmethyl ether has found application in the suppression of the germination of potato tubers on prolonged storage[3]. Derivatives of 4-nitrophenyl phenyl ether containing a wide variety of substituents in the second aromatic ring[3,5,25-34], including halogens and the trifluoromethyl and alkoxycarbonyl groups, are most widely used as herbicides in the fight against weeds infesting a wide variety of crops. These and similar compounds are obtained in high yields by the reaction of the phenoxides derived from the corresponding phenols with *p*-chloronitrobenzene and its analogues in various organic solvents and in water[35].

2-Alkyl-4,6-dinitrophenols and their esters formed with various acids, pentachlorophenol and its salts with various organic and inorganic bases[3,5], as well as 2,6-di-iodo- and 2,6-dibromo-4-cyanophenols and their salts and esters with carboxylic acids[3,5,36], known as Ioxynil and Bromoioxynil, are no less widely used as contact herbicides. These compounds are mostly employed in the fight against weeds resistant to 2,4-D preparations[3,36] in plantations of grain cereals. Ioxynil is obtained in a high yield by the iodination of 4-cyanophenol; the iodination can be also carried out electrochemically[37]. A number of other cyanophenols have been proposed as herbicides[38,39].

IV. AMINES AND QUATERNARY AMMONIUM SALTS

Amines and their derivatives have found fairly extensive agricultural applications in recent years and the scale of their practical utilisation is continuously increasing[3,5,9]. 2-Chloroethyltrimethylammonium chloride, known as Chlormequat, CCC, or TUR, is widely used in Europe as a plant growth regulator[40-55]. In doses ranging from 4 to 6 kg per hectare, chlormequat is used in the fight against the flattening of wheat and rice under conditions of increased humidity[40-43,45,48-51]. The application of this preparation to barley does not produce such an effect owing to the decomposition of chlormequat in the barley plants[46,47]. The application of chlormequat to wheat and rice has a major economic effect; for this reason, up to 50% of wheat plantations are treated, for example, in the German Federal Republic and in Finland. Chlormequat is used successfully on strawberries[44], vegetable cultures[46,47], in the growing of fruit[53] and cotton[54,55], and in viticulture[56]. In the growing of cotton, particularly satisfactory results have been obtained when the preparation was applied jointly with succinic acid[55].

A large number of chlormequat analogues have now been synthesised and investigated[57-76]. Some of these are highly active and may be of practical interest. In particular, trimethylalkylammonium salts containing a terpenoid structure[60,61], cyclohexyl and cyclohexenyl residues[74,75], and certain heterocyclic systems[64] in the hydrocarbon group are very active. Dimethylmorpholinium chloride (I) and 2-chloroethyldimethylhydrazinium chloride (II), and some of their analogues obtained by the reaction of alkyl halides with the corresponding amines or hydrazines[64,77,78], are of considerable interest. It is interesting to note that, when cereals are treated with 2-chloroethyldimethylhydrazinium chloride, their ripening is shortened by several days and the harvest is improved as a result of the increase of the number of sheaves. Dimethylmorpholinium chloride is active not only on wheat but also on barley, which is very significant, since in many regions barley is no less important than wheat.

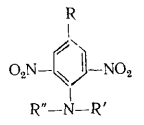


(I) (II)

The study of the growth regulating activity of sulphur analogues of chlormequat has shown that 2-chloroethyldimethylsulphonium chloride is almost three times less active than chlormequat[64]. The corresponding quaternary pyridinium, piperidinium, pyrrolidinium, pyrazinium, tetrahydrothiophenium, thiophenium, tetrahydroxanthinium, dithianium, and azepinium salts have also been investigated, but they are all less active[64]. The introduction of a halogen into the heterocycle as a rule reduces the activity of the compound. The activity of five- and seven-membered heterocyclic compounds is significantly lower than that of compounds with six atoms in the ring. The replacement of the methyl group by others in most cases likewise leads to a decrease of the growth regulating activity[64]. Ethanolammonium salts with inorganic acids also exhibit growth regulating activity[79].

Aromatic amines have found applications as herbicides in the fight against weeds in cotton, vegetables, and many

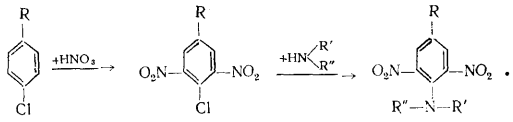
other crops[3,5,80-88]. Compounds having the general formula (III) are most widely used:



(III)

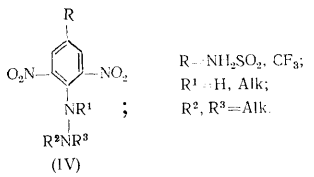
R=CH(CH$_3$)$_2$, C(CH$_3$)$_3$, CF$_3$, SO$_2$NHR, CH$_3$SO$_2$; R′=Alk; R″=Alk, ClCH$_2$CH$_2$.

Among the large number of compounds of this series, Treflan (2,6-dinitro-*NN*-dipropyl-4-trifluoromethylaniline) and nitraline (4-methylsulphonyl-2,6-dinitro-*NN*-dipropylaniline) are used in greatest amounts. These compounds can be obtained in high yields by the following procedure[3]:



Oryzalin (2,6-dinitro-*NN*-dipropyl-4-sulphonamidoaniline)[82,87], etafloraline [*N*-ethyl-*N*-(2-methylallyl)-2,6-dinitro-4-trifluoromethylaniline][81,88], Pregard*† (*N*-cyclo-propylmethyl-2,6-dinitro-*N*-propyl-4-trifluoromethylaniline), Dinir* (*NN*-diethyl-2,6-dinitro-*m*-phenylenediamine)[80], and certain others are being introduced into agricultural practice. The compounds of this group are not very toxic to mammals and are effective in the fight against weeds (in doses of 1–1.5 kg per hectare). However, one should note that certain compounds of this series are extremely toxic to fish[3].

One should also mention 2-hydroxyethylhydrazine, which is used in the USA to accelerate the growth of pineapples and to increase their crop[23]. It can be obtained by the reaction of oxiran and hydrazine. Among hydrazine derivatives, mention may be made of arylhydrazines having the general formula (IV)[90], which have been recommended as herbicides. These compounds are obtained similarly to the corresponding anilines:



(IV)

R=NH$_2$SO$_2$, CF$_3$; R^1=H, Alk; R^2, R^3=Alk.

V. CARBOXYLIC ACIDS AND THEIR DERIVATIVES

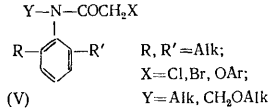
One of the most important groups of compounds physiologically active in plants are carboxylic acids, among which numerous herbicides and plant growth regulators have been found. We may mention that natural plant growth regulators such as gibberellins and heteroauxins are carboxylic acid derivatives.

Among aliphatic compounds, derivatives of trichloroacetic, monochloroacetic, dichloropropionic, and tetrafluoropropionic acids[3] and their mixtures[89] have found extensive application as herbicides. Alkali metal trichloroacetates and dichloroprotionates are most widely used, giving satisfactory results in the fight against monocotyledonous weeds in doses of 10–50 kg per hectare[5].

†Here and henceforth the spelling of authors' names marked with an asterisk is tentative (Ed. of Translation).

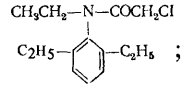
Tetrafluoropropionate salts and their mixtures with dichloropropionate salts have been used successfully recently[89].

The anilides of monochloroacetic and other acids with the general formula (V)[3,91-97], which have a low toxicity for warm-blooded animals and can be used on various crops, are of considerable interest. For example, the preparation Mechet* (VI) is used successfully in the fight against weeds in rice seedlings and Anachlor* (VII) is used in plantations of maize, soya beans, groundnuts, and other crops. Propachlor (VIII), used in the fight against weeds in vegetable crops, soya beans, etc. belongs to the same group of compounds.

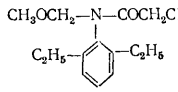


(V)

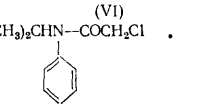
R, R′=Alk; X=Cl, Br, OAr; Y=Alk, CH$_2$OAlk



(VI)



(VII)



(VIII)

The 3,4-dichloroanilides of propionic and other acids as well as the 3-chloro-4-methylanilides of various acids have found extensive applications in the fight against weeds in various crops. A common disadvantage of this group of compounds is their relatively high toxicity to fish and also the formation of azo-compounds as a result of their metabolism in the soil[98]. The application of compounds having the general formula (V)[99], containing the furyl and tetrahydrofuryl residues at the nitrogen atom, as well as the chloralamides [1,1,1-trichloroethylideneamides] of carboxylic acids[98] has also been patented.

Among aliphatic dibasic acid derivatives, the 2,2-dimethylhydrazide of succinic acid, known as Alar, is widely used as a plant growth regulator[100-118]. Alar is used to suppress the growth of young shoots of perennial crops, which in many instances leads to a significant increase in the crop of apples and pears harvested, reduces the shedding of the fruit prior to harvesting, improves their commercial quality, facilitates the formation of the branches of young trees, and sometimes reduces the time required for the ripening of the crop. Alar is obtained in satisfactory yields by the reaction of succinic anhydride with dimethylhydrazine. The influence of Alar on the rate of ripening of fruit and the frost resistance of apple trees[100,103,104,110] on the rate of ripening of peaches[102], morello cherries[105], and plums[106], and on the harvest of pears[107-109,112], sweet cherries[111], grapes[113], alfalfa and clover[118], carrots and tomatoes[115,117], pepper[118], brussels sprouts[119], and groundnuts has been investigated. It has been noted that Alar has a favourable influence on the majority of the crops investigated, but different types of plants respond in different ways to treatment by this preparation, so that the conditions and concentrations at which the preparation gives the optimum effect should be determined for each type of plant. Alar is usually employed at a concentration of 0.5–3 g litre^{-1}.

In the USA, Alar is used to suppress the growth of young shoots of apple and pear trees, to increase the intensity of flowering, to prevent the shedding of fruit prior to harvesting and to improve their colour, to accelerate the ripening of peaches and cherries, to increase the harvest of certain types of grapes, and to improve the flowering of azaleas and chrysanthemums. The increase in the harvest of grapes when Alar is used may be very considerable.

Thus in some years American investigators succeeded in increasing the harvest by 25–30 centners [2500–3000 kg] per hectare[113].

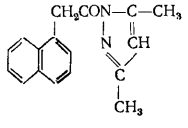
Among carboxylic acid derivatives, mention should be made of preparations which began to be used several decades ago. Such preparations include in the first place aryloxyalkanecarboxylic acids and 2-naphthylacetic acid, whose salts and amides are used to accelerate the opening of apple blossom buds and to accelerate the rooting of plants propagated by cuttings. In propagation by cuttings, the readily water-soluble salts of 2-indolylbutyric and 2-indolylacetic acids are also used[2].

TH-656 (IX), the active principle of which is 3,5-dimethyl-1-naphthylacetylpyrazole, has been proposed to accelerate the setting of mandarin fruit[120].

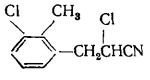
2,3,6-Trichlorobenzoic, 3,6-dichloro-2-methoxybenzoic, 3-amino-2,5-dichlorobenzoic, 2,3,6-trichlorophenylacetic, and certain other acids[3,5], which are used in mixtures with other herbicides in the form of water-soluble salts formed with inorganic and organic bases, have found extensive applications as herbicides. 2,3,5-tri-iodobenzoic acid[121–125], the application of which in doses of 125–250 g per hectare increases the harvest of soya beans[121,122], alfalfa[123], peas[124], and cotton, is a plant growth regulator. However, the effectiveness of 2,3,5-tri-iodobenzoic acid depends greatly on the type of plant[121,125].

Among carboxylic acid derivatives, mention should be made of Orthonil (X) [2-(β-chloro-β-cyanoethyl)-6-chlorotoluene], the type of action of which resembles that of abscisic acid[126–128].

Tomacone* [1-(2,4-dichlorophenoxyacetyl)-3,5-dimethylpyrazole] is used to increase the harvest of tomatoes and to obtain seedless tomatoes. The water-soluble sodium salts of α-(2,4,5-trichlorophenoxy)propionic, 4-chlorophenoxyacetic, and 2-naphthoxyacetic acids are used for the same purpose. 2-Naphthoxyacetic acid is likewise employed to improve the flowering of strawberries and pineapples. *m*-Tolylphthalamic acid, which is used in the USA to improve the harvest of cherries and Lima beans, has also been applied to obtain seedless tomatoes. α-(3-Chlorophenoxy)propionic acid is used to increase the size of plums[23].



(IX)



(X)

Despite the fact that the herbicidal and plant growth regulating properties of aryloxyalkanecarboxylic acids were discovered more than 30 years ago, the study and synthesis of new derivatives of this group are still being continued[129–146]. This is quite understandable, since the scale of the manufacture and application of this group of substances is fairly large and there is no tendency towards a decrease[9,146].

The salts and esters of 2,4-dichlorophenoxyacetic, 4-chloro-2-methylphenoxyacetic, and 2,4,5-trichlorophenoxyacetic acids, the world manufacture of which has exceeded 100 000 tonnes annually, have been most widely employed[5,9,16]. The use of 2,4,5-T has been interrupted, since the technical product has been found to contain 2,3,7,8-tetrachlorodibenzo-1,4-dioxin, which is highly toxic to warm-blooded animals and man and exhibits a powerful irritant and teratogenic activity[147]. However, after the development of methods for the elimination of the above impurity, the employment of 2,4,5-T was renewed on virtually the same scale. (In most countries the rule has been adopted that the preparation must not contain more than 0.5 mg of 2,3,7,8-tetrachlorodibenzo-1,4-dioxin per kilogram.)

It has been established that the majority of the esters of the above acids exhibit a high herbicidal activity, which is proportional to the content of the corresponding acid in the ester. Furthermore, studies have been continued on the synthesis of new esters[133,140,142]: some of them are so expensive that they can hardly have practical applications. Derivatives of aryloxyalkanehydroxamic acids[138], the sugar esters of aryloxyalkanecarboxylic acids[131], derivatives of aryloxyalkanethiocarboxylic and aryloxyalkanedithiocarboxylic acids[137,143], aryloxyalkanecarboxylic acid amides[132,145], as well as aryloxyacrylic acid[135] have also been synthesised. We may note that Nametkin and his coworkers have made a significant contribution to the field of aryloxyalkanecarboxylic acids[1].

The esters formed by 1-naphthylacetic acid with poly(ethylene glycol) continue to be used for the setting of mandarin fruit[148] and unsaturated alkoxycarboxylic acid are used in the treatment of oranges[149]. Various derivatives of fluorinecarboxylic acid (XI) have found fairly extensive applications as herbicides and plant growth regulators[3,5,150–153].

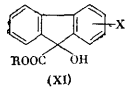
The employment of the imide of oxoglutaric acid[154] and of α-amino(hydroxyphenyl)butyric acid[155] to stimulate plant growth by treating the seeds prior to sowing has been suggested. *trans*-2-Amino-α-2-aminoethoxybutenoic acid in doses of 1–4 kg per hectare has been proposed as a herbicide to be used against beardgrass, darnel, cocklebur and other weeds.

The esters of substituted phenylpropionic acids are of interest as selective herbicides[158]; methyl α-chloro-(*p*-chlorophenyl)propionate is used in the fight against bearded oats in wheat[3,5]. It can be obtained in high yields by the following procedure[157]:

$$ClC_6H_4NH_2HCl \xrightarrow{+HNO_2} ClC_6H_4N_2Cl \xrightarrow{+CH_2=CHCN} \rightarrow ClC_6H_4CH_2CHClCN \xrightarrow{+H_2O+CH_3OH} ClC_6H_4CH_2CHClCOOCH_3 .$$

The esters of aromatic thiocarboxylic acids have also been proposed as herbicides[159].

Among carbonyl compounds, numerous aldehydes and ketones have been proposed as herbicides and plant growth regulators[160–166]. Thus C_4–C_{18} ketones have been suggested for the chemical sucker control in tobacco[160], hexahalogenoacetones have been suggested as inhibitors of the germination of potato tubers[161], and aromatic and aliphatic-aromatic ketones have been suggested as herbicides[162–165]. Both aryloxyacetophenones[166] and aminoketones[163] have been proposed as selective herbicides.



(XI)

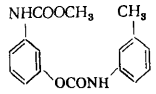
Together with phenoxyalkanecarboxylic acids, naphthoxyalkanecarboxylic acids and their derivatives, the study of which was first began in Nametkin's laboratory[1], have been recommended in recent years for practical applications. *NN*-Diethyl-1-naphthoxy-2-propionamide, recommended as a herbicide effective against weeds in cabbage, may serve as an example of such preparations[167,168].

Among carboxylic acid derivatives, substances have been found, which are used as herbicide antidotes[169]. The anhydride of 1,8-dinaphthoic acid and the diarylamide of dichloroacetic acid may serve as examples of compounds

of this kind. The latter has been fairly widely used to protect maize from damage by herbicides consisting of thiocarbamic acid derivatives. Mixtures of Eptam with diaryldichloroacetamide known as Eradicaine are nowadays used in the fight against weeds in maize plantations. Eradicaine contains 8.3% of the diallylamide of dichloroacetic acid and 91.7% of Eptam.

VI. CARBAMIC AND THIOCARBAMIC ACID DERIVATIVES

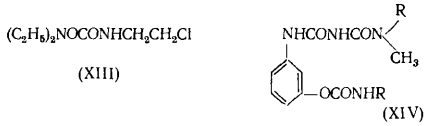
One of the fairly numerous groups of compounds with high physiological activity in plants comprises derivatives of carbamic and thiocarbamic acids[2,3]. Several decades ago, preparations such as IPC, Chloro-IPC and certain others found practical applications. During recent years, the range of arylcarbamic acid derivatives has been constantly expanding; several tens of carbamic derivatives are used at the present time[3,5,170-196]. For example, it has been found that isopropyl *N*-(3-chlorophenyl)-*N*-propoxymethylcarbamate[170], which is moderately toxic to animals, can be used as a plant growth regulator for the retardation of the growth of grasses, sucker control in tobacco, and in a number of other instances. Betanal, the active principle of which is Phenmedipham (XII)[3],



(XII)

is fairly widely used as a herbicide in the fight against weeds in sugar beet plantations. A large number of analogues of this preparation[171,182-196], including carbamic acid derivatives containing a urea residue together with the carbamoyl residue in the molecule[182,183,185,188,189,191,192,196], have now been synthesised and proposed as herbicides. It is interesting to note that, among such derivatives, *meta*-substituted compounds exhibit the highest activity; *para*- and *ortho*-derivatives are much less physiologically active in plants.

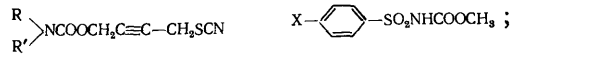
Oxime carbamates have also been suggested as herbicides and plant growth regulators[178-181]. Thus it has been suggested that compound (XIII)[86] be used to spray orange trees in order to facilitate harvesting and that carbamoylarylenebiurets (XIV) be used as herbicides[196]:



(XIII) (XIV)

It is of interest that certain mixtures of carbamates act in the soil much longer than each component separately. For example, a 4:1 mixture of Chloro-IPC and the 4-chlorophenyl ester of cyclohexylcarbamic acid are active for almost 14 weeks, whereas Chloro-IPC alone remains in the soil for not more than 4 weeks when used in the same doses[197].

Among the carbamic acid derivatives investigated, bifunctional derivatives containing various other functional groups apart from the carbamic acid residue have been found recently to occupy an important place[181,191,195]. In particular, compounds having the general formula (XV)[198] have been suggested as agents suitable in the fight against foxtail and compounds having the general formula (XVI) have been proposed as herbicides to combat other weeds[199].



(XV) (XVI) X=NH_2, CH_3NH .

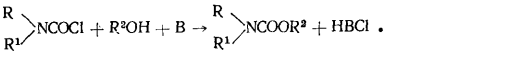
The most convenient methods for the synthesis of the alkyl and aryl esters of aryl- or alkyl-carbamic acids involve reactions of the corresponding isocyanates with alcohols or phenols[3]:

$$RNCO + R^1OH \rightarrow RNHCOOR^1$$

or of chlorocarbonates with the corresponding amines:

$$ROCOCl + NH_2R^1 \rightarrow ROCONHR^1 + HCl .$$

Carbamic acid esters can also be obtained by the reaction of phenols or alcohols with carbamoyl chlorides in the presence of hydrogen chloride acceptors[5]:



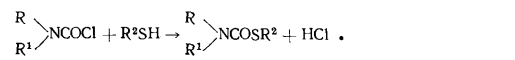
Together with carbamic acid derivatives, those of thio- and dithio-carbamic acids have found extensive applications in agriculture in the fight against weeds in various crops[3,5]. More than 15 derivatives of thiocarbamic acids, which include preparations such as Diallate, Triallate, Yalan, Tillam, Eptam, Vernolate, Sutan, Ro-Neet, Saturn and others, have now found practical applications[3,5]. Thiocarbamic acids are used in the fight against weeds in wheat, rice, maize, sugar beet, soya beans, certain vegetables and other crops. The majority of preparations of this class are introduced into the soil and then dug into a depth of 2–5 cm. The latter is necessary because of the relatively high volatility of this group of substances.

Thiocarbamic acid esters have found applications not only independently but also in mixtures with herbicide antidotes[169] and various other compounds[200]. A very large number of aliphatic, alicyclic, aromatic and heterocyclic derivatives of thiocarbamic acid have now been described; the search for new preparations belonging to this class is being vigorously continued[201-222].

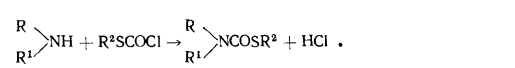
Derivatives of thiocarbamic acid obtained from substituted cyclopropylamines[201], alkyleneimines[220,221], and alkyl- and dialkyl-amines, derivatives containing various substituents in the ester group[202,204], the benzyl and 2-chlorobenzyl esters of dialkylthiocarbamic acids[205,206], the 4-substituted benzyl esters of dialkylcarbamic acids[207-216], the thienylmethyl esters of dialkylthiocarbamic acids[217,218], the pyridylalkyl esters of thiocarbamic acids[219], and many others have been described recently. Certain sulphenyl carbamates[219,223], which are the first products of the metabolism of thiocarbamic esters in the soil and other objects in the environment[223], also possess herbicidal properties.

Three main procedures have been described for the preparation of various types of thiocarbamic esters[3,203,204,211,212].

The interaction of mercaptans with carbamoyl chlorides:

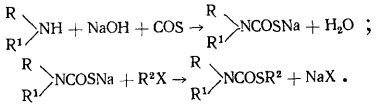


The interaction of alkyl chlorothiocarbonates with amines:



Both reactions take place satisfactorily in the presence of hydrogen chloride acceptors.

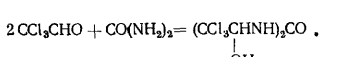
The reaction of salts of dialkylthiocarbamic acid with alkyl halides constitutes an interesting general method for the synthesis of thiolocarbamates. The salts required are formed in high yields when amines and strong alkalis react with carbonyl sulphide:



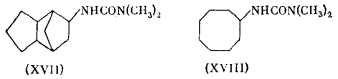
II. UREA AND THIOUREA DERIVATIVES

Urea and thiourea derivatives constitute one of the most important classes of chemicals which have found fairly extensive applications in the agriculture of different countries[3,5,224-289]. We may note that more than 40 different aliphatic, alicyclic, aromatic, and heterocyclic urea derivatives are used nowadays in the fight against weeds in a wide variety of agricultural crops.

Among the aliphatic urea derivatives, we may mention dichloralurea, used in the fight against grass weeds in sugar beet and certain other crops[2]. Dichloralurea can be synthesised in high yields by the reaction between urea and chloral[290]:

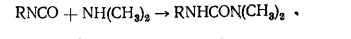


A number of asymmetric alicyclic ureas have been proposed as herbicides[3,252-257]; among these *NN*-dimethyl-*N'*-(perhydro-4,7-methylene-5-indanyl)urea, known under the commercial name of Herban (**XVII**), has found practical applications. This preparation is used in the fight against weeds in plantations of cotton plants, soya beans, peas, potatoes, and certain other crops in doses of 1.5–4 kg per hectare. *N*-Cyclo-octyl-*N'N'*-dimethylurea or cycluron (**XVIII**) has also found some applications[3]; it is used in plantations of beet and other vegetables in mixtures with other preparations. Other alicyclic ureas are also being investigated[252-257]:

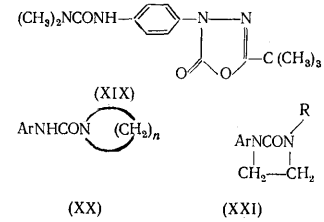


(XVII) (XVIII)

Ureas of this type are usually obtained by the reaction of the corresponding alicyclic isocyanates with amines[252-257]:



Aliphatic-aromatic derivatives of urea, some of which exhibit a highly selective action and may be used for a wide variety of crops, have found the most extensive applications. For example, 4-isopropylphenyl-*NN'*-dimethylurea has been suggested as an agent against weeds in winter wheat plantations[227,233]; 3-chloro-4-methylphenyl-*NN'*-dimethylurea[226,241] and its homologues and 3-chloro-4-methoxyphenyl-*NN*-dimethylurea and its homologues[228,234,235,239,242,245] also give satisfactory results in the fight against weeds in wheat. Cotoran [*NN*-dimethyl-*N'*-(3-trifluoromethylphenyl)urea], *N*-(3-chloro-4-trifluoromethylphenyl)-*N'N'*-dimethylurea[232], *N*-(3-chloro-4-trifluoromethoxyphenyl)-*N'N'*-dimethylurea, and certain others are widely used to combat weeds among cotton plants and other crops. Practical applications have also been suggested for *N*-(3-tetrafluoroethoxyphenyl)-*N'N'*-dimethylurea[225]. A series of urea derivatives containing various acyl groups at the nitrogen atom[236-238] as well as compounds having the general formula (**XIX**)[259-261], containing a wide variety of substituents in the aromatic group, have been proposed. Compounds having the general formulae (**XX**)[231], (**XXI**)[268], and certain others[269,270] can be classified as urea derivatives:



(XIX)

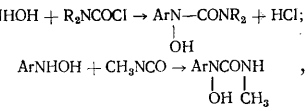
(XX) (XXI)

Complexes of substituted ureas with acids[251] and urea derivatives of hydroxylamine[3,258] containing a hydroxy-group [compound (**XXII**)][3,181] or a methoxy-group [compound (**XXIII**)][3,258] at one of the nitrogen atoms have likewise been proposed as herbicides:

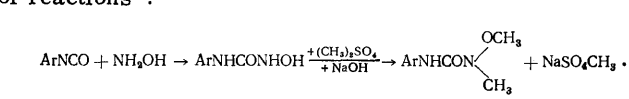


(XXII) (XXIII)

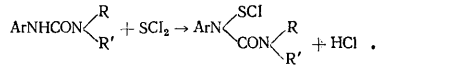
Compounds (**XXII**) are obtained in high yields by the reaction of arylhydroxylamines with dialkylcarbamoyl chlorides or alkyl isocyanates[3]:



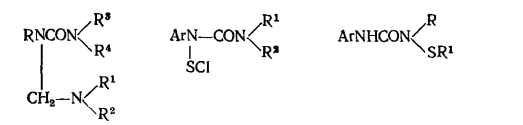
and compounds (**XXIII**) are obtained by the following series of reactions[3]:



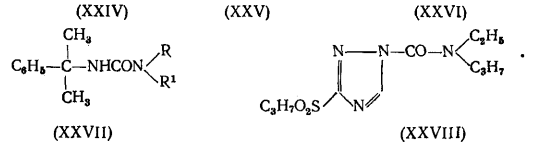
Compounds having the general formulae (**XXIV**)[244], (**XXV**), and (**XXVI**)[262-266] have been proposed recently as herbicides. Compounds (**XXV**) are obtained in high yields by the reaction of the corresponding substituted ureas with sulphur dichloride in pyridine or another similar solvent[262]:



Chlorine is readily substituted in these compounds by various other groups[263]. Compounds having the general formula (**XXVII**) have also been put forward as herbicides[246,249,253]:



(XXIV) (XXV) (XXVI)



(XXVII) (XXVIII)

Numerous heterocyclic ureas, including representatives of a wide variety of classes of compounds, have been

suggested as agents suitable in the fight against undesirable plants. 1-(*N*-Ethyl-*N*-propylcarbamoyl)-3-propylsulphonyl-1,2,4-triazole (**XXVIII**) may serve as an example[230]. Urea herbicides include derivatives of 1,2,4-oxadiazole[287], 1,2,4-thiazole[287], furfural and pyran[275], thiazole[283,286], isothiazole[284], 1,3,4-thiadiazole[271,272,276], dichlorothiazole[278], sulphonylthiadiazole[279], pyridine[267], and certain other heterocyclic compounds[273,280-282,285,288]. Certain heterocyclic ureas have found practical applications. These include in the first place *N*-(2-benzothiazolyl)-*N'*-methylurea (Benzthiazuron), *N*-benzothiazolyl-*NN'*-dimethylurea (Metabenzthiazuron), *N*-[5-butyl-2-(1,3,4-thiadiazolyl)]-*NN'*-dimethylurea (Tebuthiuron), 1,3-dimethyl-1-[5-trifluoromethyl-2-(1,3,4-thiadiazolyl)]-urea (Thiazfluron) and others.

Despite the fact that a very large number of urea derivatives have now been described and investigated as herbicides and plant growth regulators, the research in this field is being vigorously continued and new preparations, promising for practical applications, are being systematically produced.

Certain conclusions concerning the dependence of herbicidal activity on the structure of the urea derivatives can be reached on the basis of the available data. Since this problem cannot be dealt with in detail here, we shall merely mention certain general postulates concerning substituted dialkylarylureas. Dialkylarylureas containing not more than two substituents in the benzene residue and with at least one of the *ortho*-positions relative to the amide group containing hydrogen are the most active herbicides. The total number of hydrogen atoms in the two alkyl residues at the nitrogen atom must not be more than five; in the presence of a larger number of carbon atoms in these groups, the activity of the compound falls. However, this does not apply to arylcycloalkylureas. For example, *N*-(2-methylcyclohexyl)-*N'*-phenylurea is an active herbicide. With increase of the number of carbon atoms in the alkyl or cycloalkyl residues, the overall herbicidal activity falls, but the selectivity of the action of the preparation rises.

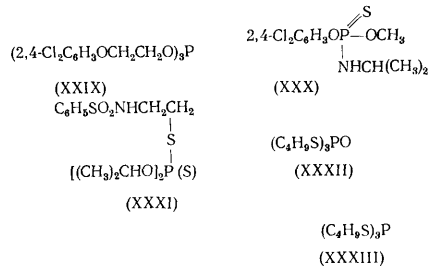
Among *NN*-dialkyl-*N'*-arylureas, the chloro- and iodo-derivatives are the most and least active respectively. Ureas containing substituents in the 3,4-positions of the phenyl group show the most selective activity. *NN*-Dialkyl-*N'*-naphthylureas exhibit a weaker herbicidal activity. The derivatives of thiourea among which only *NN*-dimethyl-*N'*-(3-methylphenyl)thiourea has found a practical application are of lesser interest as herbicides. Other thiourea derivatives are more interesting as fungicides[3].

VIII. ORGANOPHOSPHORUS AND ORGANOARSENIC COMPOUNDS

Among arsenic compounds, arsenic acid has found a practical application for the defoliation and desiccation of the cotton plant[3,22]; in the USA considerable areas of cotton plantations are treated with this substance. Salts of methylarsenic and cacodylic acids are also used in the fight against weeds. However, one should note that the wide-scale employment of arsenic in agriculture leads to its accumulation in the soil and in the plants[291]. Salts of methylarsenic and cacodylic acids have been used on a particularly large scale in mixtures with various other herbicides[289] and also in the fight against certain weeds in meadows[293].

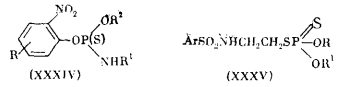
The herbicidal and growth regulating properties of organophosphorus compounds have been investigated on a large scale during recent years and considerable advances have been achieved in this field[293-371]. Among the organophosphorus compounds investigated, there are representatives of a wide variety of phosphorus derivatives with different biological activities. The interest in organophosphorus compounds is quite understandable, since the majority of these compounds readily decompose in the soil with formation of phosphoric acid and other simple compounds, leaving practically no toxic residues in the environment[291,372]. The accumulation of organophosphorus compounds in the environment has not so far been observed[372].

Some of the first organophosphorus herbicides were the preparations Falone (**XXIX**), Zytron (**XXX**), and Prefar (**XXXI**), which have found comparatively limited applications. Butifos (**XXXII**) and Merphos (**XXXIII**) are used on a much larger scale as defoliants for the removal of leaves from the cotton plant prior to harvesting[22].



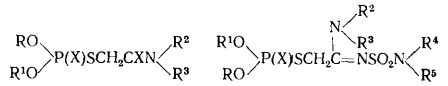
(XXIX) (XXX) (XXXI) (XXXII) (XXXIII)

A large number of Zytron analogues containing the nitro-group in the 2-position of the phenyl substituent have been synthesised recently[333,340,344,352,367,368,370,374]; compounds of this type, having the general formula (**XXXIV**), are at present being investigated in Japan under experimental industrial conditions.



(XXXIV) (XXXV)

Together with the synthesis and study of a large number of Prefar analogues having the general formula (**XXXV**)[347], numerous compounds having the general formula (**XXXVI**)[332,335,345,351] and containing aliphatic[357], aromatic[351] and heterocyclic[345] residues at the nitrogen atom, have been synthesised. In most instances, these compounds exhibit selective herbicidal activity; among them, there are derivatives of both phosphorothioic and phosphorodithioic acids[332].



(XXXVI) (XXXVII)

Prefar and its analogues can be synthesised by the following procedure[347]:

$$ArSO_2NHCH_2CH_2Cl + NaSP(S)(OR)_2 \rightarrow (RO)_2P(S)SCH_2CH_2NHSO_2Ar + NaCl.$$

A number of other phosphates[326], phosphorothioates[349,350,359,360], phosphoramidates, and phosphoramidothioates[327,328] have been synthesised and their herbicidal and growth regulating properties investigated. For example, *SS*-dialkyl phosphorochloridodithioates, obtained by the reaction of dialkyl disulphides with phosphorus trichloride in the presence of anhydrous aluminium chloride, have been proposed as defoliants[348], while phosphorus-containing

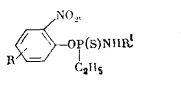
derivatives of *s*-triazine[346] and 2,3,6-trichlorobenzoylphosphazo-*N*-aryliminotrichloroacyl[338] have been proposed as herbicides.

The use of phosphonate analogues of compounds (XXXIV), having the general formula (XXXVIII)[375], which are safe for the cotton plant, carrots, potatoes, and certain other crops, has been patented.

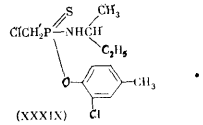
Systematic studies on the ester-amides of methylphosphonic and methylphosphonothioic acids and their derivatives, containing various substituents in the methyl group attached to the phosphorus atom, have shown that derivatives of chloromethylphosphonothioic acid exhibit the highest activity[376-379] and the ester-amides of alkylphosphonothioic acids can be arranged in the following sequence in terms of their decreasing herbicidal activity[376-379]:

$$ClCH_2{-}P{>}CH_3{-}P{=}ROCH_2{-}P{>}ClCH_2CH_2{-}P{>}C_2H_5{-}P{>}C_3H_7{-}P{>}RSCH_2{-}P{>}C_6H_5{-}P$$

The study of the conformational transitions of the ester-amides of chloromethylphosphonothioic acid has shown that compounds with the smallest difference between the free energies of the rotational isomers have the highest herbicidal activity[377,379]. This observation can also explain the lower herbicidal activity of phosphonates compared with phosphonothioates[377]. In this group of substances, the preparation known as Isophos-3 (XXXIX) is of considerable interest[379]:



(XXXVIII)

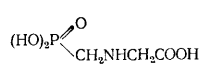


(XXXIX)

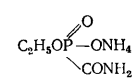
The use of Isophos-3 gives good results in the fight against weeds in rice, wheat, maize, soya beans, tomatoes, and a number of other crops. This preparation is particularly effective in the fight against millet-like weeds[379]. A large number of Isophos analogues with herbicidal activity have now been synthesised[380,381]. It is interesting to note that the ester-amides of chloromethylphosphonothioic acid containing secondary amine residues are the most active. The structure of the ester residue also has a considerable influence[379].

Phosphonomethylglycine (XL), which exhibits powerful herbicidal properties in the form of its salts with aliphatic amines, being effective against monocotyledonons perennial weeds, including witchgrass, is of great interest. This preparation, known as glyphosate, is obtained by the reaction of chloromethylphosphonic acid or its derivatives with glycine[371]. A large number of derivatives and mixtures of glyphosate with various other herbicides have been described[342,353,358,362,363].

Various carbamoylphosphonates have been proposed as growth regulators and herbicides[329,336,341,343,382], among which the ammonium salt of *O*-ethyl carbamoylphosphonic acid (XLI)[382] has found practical applications in the fight against certain perennial plants.



(XL)



(XLI)

2-Chloroethylphosphonic acid and some of its derivatives[292-324] (the acid is known as Ethrel, Ethephon, etc.) have found extensive applications as plant growth regulators. The action of 2-chloroethylphosphonic acid is based on the fact that, at pH > 4.5, ethylene, which possesses a high growth activating activity, is evolved. 2-Chloroethylphosphonic acid is obtained by the hydrolysis of its 2-chloroethyl ester with hydrochloric acid or hydrogen chloride[325,373,383]. Satisfactory yields are obtained when the most concentrated hydrochloric acid is employed. The 2-chloroethyl 2-chloroethylphosphonate required for synthesis is obtained in high yields by Kabachnik's method[383] from tri-(2-chloroethyl) phosphite. Together with 2-chloroethylphosphonic acid, its various derivatives[331,337,361], homologues[355,375], and many other phosphonic acid derivatives[354,366,384] have been proposed as plant growth regulators.

Depending on the concentration of the preparation and the stage of development and species of the plant, 2-chloroethylphosphonic acid can have various physiological effects: stimulation or inhibition of growth, the awakening of dormant buds, the acceleration of the ripening of fruit and vegetables, the acceleration of axillary branching of plants, the induction of flowering, the increase of frost resistance of buds, and the acceleration of the shedding of leaves, flowers, and fruit[300,301]. When Ethrel was used to vernalise wheat, an increase of the earing of the seedlings by a factor of 8–53 compared with the control seeds was noted[302]. The use of 2-chloroethylphosphonic acid on tomatoes[303-309], mandarin oranges[310,311], lemons, oranges, and grapefruits[311], peaches[312], cucumbers[313-315], cherries, onions[316], strawberries[317], hazelnuts[318], groundnuts[319], walnuts[320,321], sunflowers[322,323], tobacco[323], and the cotton plant[298] has yielded satisfactory results in the acceleration of ripening and the facilitation of the mechanisation of harvesting.

Ethrel is particularly promising for the mechanisation of the harvesting of fruit including citrus fruit. When the preparation is used, the facilitation of the removal of fruit from the plant is accompanied by the acceleration of their ripening, which promotes an increase in the harvest and an improvement in its quality. Thus peaches ripen 5 days earlier than usual[312] and the crop of tomatoes increases by 20–30%[307] and that of strawberries by 36–44%.[317] Ethrel is also an effective agent for the termination of the dormant state of groundnuts[319]. Depending on its purpose, Ethrel is used at concentrations ranging from 0.25 to 10 g litre^{-1}. It is used as a concentration of 0.5–1 g litre^{-1} as a plant growth regulator and at higher concentrations as a defoliant. Depending on the plant to be treated, its dose is 250–3000 g per hectare and the employment of even the highest concentrations of the preparation is economically justified. Ethrel leaves no toxic residues on the plants, since it decomposes almost completely with formation of phosphoric acid, which is assimilated by the plants.

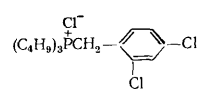
It is interesting to note that certain derivatives of 2-chloroethylsilicon[369,385] and the esters of 2-chloroethylphosphinic acid[386] have properties resembling those of Ethrel.

We may note that Ethrel is of interest also as a gametocide[387], since at concentrations of 2–3 g litre^{-1} it completely sterilises the male pollen of plants, which is of interest for the preparation of hybrid seeds.

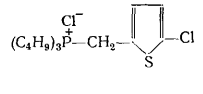
Among phosphonic acid derivatives, mention must be made of *NN*-di(phosphonomethyl)glycine, which has been proposed for the acceleration of the ripening of sugar cane and for the increase of its sugar content[388].

Together with phosphorus acid derivatives, quaternary phosphonium salts have found practical applications in plant cultivation[293-297,365], the preparation Phosfon-D (XLII) being the best known representative of these. Phosfon-D is used as a broad-spectrum retarding agent mainly in soil under cover in relation to flowering plants. The CHE-8728 preparation [tributyl-2-chlorothienylmethylphospho-

nium chloride (XLIII)], recommended for increasing the crop of cotton, soya beans, kidney beans, and sugar cane, has been widely investigated recently[293-297,365]. When the above plants were sprayed with aqueous solutions of the preparation (25–30 mg litre^{-1}), the crop increased by 7–15%.



(XLII)



(XLIII)

Tributyl-2-chlorothienylmethylphosphonium chloride is obtained in high yields by the reaction of tributylphosphine with 2-chloro-5-chloromethylthiophen[365]. The tributylphosphine required for the synthesis can be obtained from tributylaluminium and phosphorus trichloride. According to patent data, trialkyl-2-chlorothienylammonium salts also possess plant growth regulating properties[334]. It is seen from the above by no means complete survey that organophosphorus compounds occupy a firm position in agriculture both as herbicides and as plant growth regulators.

IX. HETEROCYCLIC COMPOUNDS OF DIFFERENT SERIES

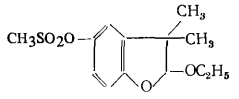
Heterocyclic compounds of different series include the greatest number of substances physiologically active in plants, which have found practical applications in agriculture[3]. Indolylacetic acid (heteroauxin) and indolylbutyric acid, which are still widely used to accelerate the rooting of plants in their vegetative propagation by cuttings[3], as well as maleic acid hydrazide, used to inhibit plant growth[391], a rational method for the manufacture of which had been developed in Nametkin's laboratory[2], have been known for the longest time.

A large number of modern herbicides are pyridine derivatives, among which the quaternary salts of 4,4′-bipyridyl and 2,2′-bipyridyl occupy the first place as regards the scale of manufacture and applications[389]; the former are obtained by the alkylation of 4,4′-bipyridyl using various alkylating agents and the latter by the reaction of dibromoethane with 2,2′-bipyridyl[389,390].

4-Amino-3,5,6-trichloropicolinic acid, which is exceptionally long acting, is a broad-spectrum herbicide[3,4].

Among pyridine derivatives, we may also mention tetrachloropyridinol, dichlorodifluoropyridinol[3], the esters and other derivatives of 4-amino-3,5,6-trichloropicolinic acid[392], 3,5,6-trichloropyridylacetic acid[393], sulpho- and nitro-derivatives of chloropyridine[394-396], polychlorocyano- and dicyano-pyridines[396,397], 3,5-dichloroalkoxyethoxypyridines[398], 3,5-difluoro-2,4,6-trimethoxypyridine[399], 2-amino-6-chloro-4-trichloromethylpyridine[400], 2,3,5,6-tetrahalogeno-4-mercaptopyridines[401], polyhalogenopyridines[402-404], perchlorovinylcyanopyridine[405], halogenoalkylpyridines[406], polysubstituted dipyridylamines[407], and sulphonium derivatives of polychloropyridines[408,409], which have been proposed as plant growth regulators and herbicides. We may also note that substituted pyrrolidines[410] and maleimides[411] have been suggested as plant growth regulators.

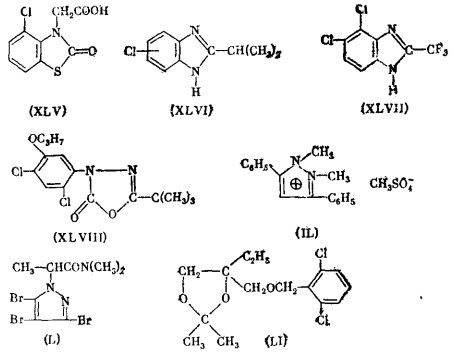
Among oxygen-containing heterocyclic compounds, 6,8-dichlorochromone[412] and various ethers of substituted hydroxytetrahydrobenzofuran[413-415] have been proposed as herbicides. In this group of preparations, 2-ethoxy-2,3-dihydro-3,3-dimethyl-5-benzofurylmethanesulphonate (XLIV), known under the commercial name Nortron, is of considerable practical interest. This preparation is used in the fight against weeds in sugar beet plantations[415]. It can be obtained in high yield by the reaction of 1-ethoxy-2,3-dihydro-5-hydroxy-3,3-dimethylbenzofuran with methanesulphonyl chloride in the presence of hydrogen chloride acceptors[414]. A number of other derivatives of dihydrobenzofuran[413,414], some of which also exhibit herbicidal activity but have not so far found practical applications, can be synthesised by a similar procedure.



(XLIV)

Numerous studies have been devoted to the herbicidal and plant growth regulating properties of five- and six-membered heterocyclic compounds with two heteroatoms in the ring, including derivatives of imidazoline[416,417], benzimidazoline and benzimidazole[418-420], indazole[421], pyrazole[422-425], oxazole and oxazolidine[426], thiazolidine and thiazole[427-429], isothiazole[430], hydantoin[431-434], and certain others.

Among the classes of heterocyclic compounds enumerated above, the following have found practical applications: Benazolin (XLV), BKh-584 (XLVI), Chlorofluorazole (XLVII), RP-17623 (XLVIII), Diphensoquat* (XLIX), *NN*-dimethyl-2-(3,4,5-tribromo-1-pyrazolyl)propionamide (L), and certain others have found practical applications. Benzglycerite* (LI)[435] is a heterocyclic compound with two oxygen atoms in the ring, which has found practical applications.



(XLV) (XLVI) (XLVII)

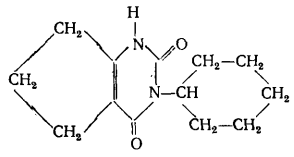
(XLVIII) (IL)

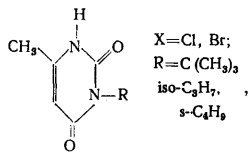
(L) (LI)

Heterocyclic compounds with two heteroatoms in the ring have found even wider practical applications. Substituted uracils[3,4,436,437], pyrimidines[438-443], and pyrazines and pyridazinones[444-453] are used on the largest scale. The most frequently used compounds of this group are Lenacil (LII) (in the fight against weeds affecting various useful plants), uracil derivatives having the general formula (LIII), Pyramin (LIV) (in the fight against weeds in sugar beet plantations), 3-phenoxypyridazine (LV), and certain others.

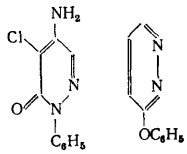
Cyclopropyl-(4-methoxyphenyl)-5-pyrimidinylmethanol (LVI) has found some applications as a plant growth regulator for the improvement of the flowering of chrysanthemums, lilies, and peonies[454]; it is employed as a spray

in the form of a 0.026% solution on plants or in the treatment of soil.

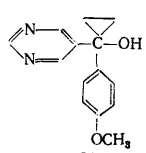

(LII)



(LIII)


(LIV)

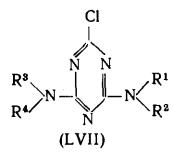
(LV)

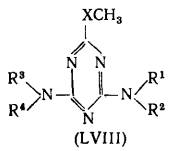

(LVI)

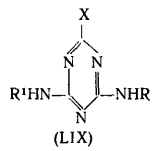
A large number of analogues of the above compounds have been synthesised and some of them may be of significant practical interest. However, their investigation has not yet been completed. There is no doubt that many interesting compounds physiologically active in plants will be found among them.

Heterocyclic compounds with three and more heteroatoms in the ring, including triazole[3], *s*-triazine[3,455-476] tetrahydro-*s*-triazine[479-482], asymmetric triazine[477,478,482], 2,2-dioxybenzo-2,1,3-thiadiazine[3,483], thiadiazole[485], oxadiazole[486], and others[484,487-491] have been investigated in detail.

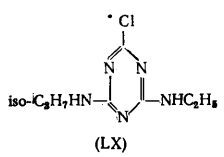
Derivatives of *s*-triazine, having the general formulae (LVII), (LVIII) and (LIX), which are readily obtained by the substitution of chlorine in cyanuryl chloride by the appropriate groups, have been most widely used as herbicides.

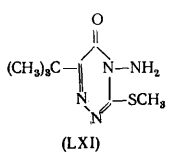

(LVII)

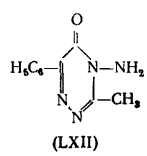

(LVIII)


(LIX)

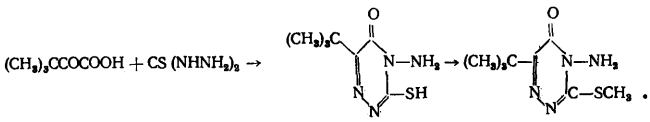
Derivatives of *s*-triazine occupy one of the leading places[9] among other preparations in terms of the scale of manufacture and their applications in the fight against weeds in various plantations. It is sufficient to point out that Atrazine (LX) alone is used in amounts up to 40 000 tonnes annually in the fight against weeds in maize plantations[492].


(LX)


(LXI)

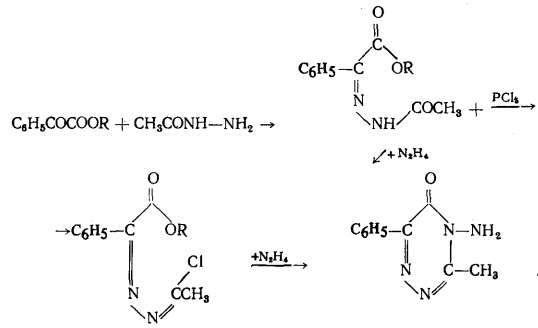

(LXII)

The first herbicide among derivatives of asymmetric thiazine is Metribuzin (Sencor) (LXI), obtained by the following procedure[477];



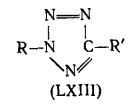
This preparation is used in the fight against weeds in soya bean, tomato, potato, and alfalfa plantations.

Another interesting preparation of this series is Metametron*[477] (LXII), obtained by the following reactions:



Metametron* has been proposed as an agent against weeds in sugar beet plantations. Particularly satisfactory results have been obtained when it was used together with certain chloroacetanilide derivatives.

Tetrazoles having the general formula (LXIII) have been proposed as plant growth regulators, inhibiting the growth of shoots and stems of various plants[489,491]:


(LXIII)

---o0o---

It has not been possible to characterise fully in this review the research designed to discover and develop new chemical weed killers and plant growth regulators, but the examples quoted are sufficient to give a general idea about the scale of such studies and about the importance which chemical preparations have assumed in plant cultivation.

REFERENCES

1. S.S.Nametkin, "Sobranie Trudov" (Collected Works), Izd.Akad.Nauk SSSR, Moscow, 1954, Vol.1, p.695.
2. N.N.Mel'nikov and Yu.A.Baskakov, "Khimiya Gerbitsidov i Regulatorov Rosta Rastenii" (The Chemistry of Herbicides and Plant Growth Regulators), Goskhimizdat, Moscow, 1962, p.723.
3. N.N.Mel'nikov, "Khimiya i Tekhnologiya Pestitsidov" (The Chemistry and Technology of Pesticides), Izd.Khimiya, Moscow, 1974, p.766.
4. N.N.Mel'nikov and N.N.Tuturina, "Khimiya v Sel'skom Khozyaistve, 13, 841 (1975).
5. H.Kurth, "Chemische Unkrautbekämpfung", VEB G. Fischer Verlag, Jena, 1975, p.564.
6. K.E.Ovcharov and M.I.Shtil'man, Uspekhi Khim., 43, 1282 (1974) [Russ.Chem.Rev., No.7 (1974)].
7. N.S.Boiko, Khimiya v Sel'skom Khozyaistve, 13, 44 (1974).
8. M.A.Fedin and M.N.Gysska, Khimiya v Sel'skom Khozyaistve, 13, 41 (1975).
9. Farm.Chem., 138, No.9, 45-48 (1975).
10. R.F.Norman, Proceedings 12th British Weed Control Conference, 3, 917 (1974).
11. J.M.Winchester, Proceedings 12th British Weed Control Conference, 3, 987 (1974).
12. T.H.Thomas, Proceedings 12th British Weed Control Conference, 3, 949 (1974).

13. V. A. Zakharenko, "Materialy VIII Mezhdunarodnogo Kongressa po Zashchite Rastenii" (Proceedings of the 8th International Congress on Plant Protection), Moscow, 1975, Vol. 2, p. 6.
14. N. G. Keiserukhskii, "Materialy VIII Mezhdunarodnogo Kongressa po Zashchite Rastenii" (Proceedings of the 8th International Congress on Plant Protection), Moscow, 1975, Vol. 2, p. 12.
15. D. L. Carr (Editor), "Plant Growth Substances, 1970", Springer, Berlin, 1972.
16. F. M. Ashton and A. S. Crafts, "Mode of Action of Herbicides", John Wiley and Sons, New York, 1973, p. 504.
17. L. P. Hanson, "Plant Growth Regulators", New York–London, 1973
18. L. Audus (Editor), "Plant Growth Substances", London, 1972.
19. T. H. Thomas, Pesticide Sci., 5, 87 (1974).
20. O. N. Kulaeva, "Tsitokininy Ikh Struktura i Funktsii" (The Structure and Functions of Cytokinins), Izd. Nauka, Moscow, 1973.
21. G. S. Muromtsev and V. N. Agnistikova, "Gormony Rastenii Gibberelliny" (Plant Hormones—Gibberellins), Izd. Nauka, Moscow, 1973.
22. L. D. Stonov, "Defolianty i Desikanty" (Defoliants and Desiccants), Izd. Khimiya, Moscow, 1973.
23. "Farm Chemicals Handbook '75", Meister Publishing Corp., Willoghby, Ohio, 1975.
24. W. K. Collins et al., Tobacco, 76, No. 24, 27–29 (1970).
25. R. Y. Yih and C. Swithenbank, J. Agric. Food Chem., 23, 592 (1975).
26. H. O. Bayer et al., US P. 3 798 276 (1974).
27. Y. Abe et al., US P. 3 821 312 (1972).
28. Y. Abe et al., US P. 3 813 444 (1974).
29. I. Shigehara et al., US P. 3 849 503 (1974).
30. L. Rohe et al., BRD Appl. 2 333 848 (1975); Ref. Zhur. Khim., 190 441 (1975).
31. V. Kato and T. Toyama, Japanese P. 49–45384 (1974); Ref. Zhur. Khim., 190 442 (1975).
32. V. Konecny and L. Kuruc, Czech. P. 146 866 (1973); Ref. Zhur. Khim., 190 440 (1975).
33. A. Creuzburg et al., DDR P. 110 152 (1974).
34. H. S. Gill and L. S. Brar, PANS, 21, 182 (1975).
35. Romanian P. 55 500 (1973); Ref. Zhur. Khim., 180 445 (1975).
36. B. Savory and C. J. Hibbitt et al., Pestic. Sci., 6, 145 (1975).
37. French P. 2 173 466 (1973).
38. E. Klauke, BRD Appl. 2 214 058 (1973); Ref. Zhur. Khim., 22N672 (1974).
39. Austr. P. 272 749 (1969); Ref. Zhur. Khim., 200 365 (1975).
40. E. I. Porot'kin and T. A. Demidova, Khimiya v Sel'skom Khozyaistve, 10, 609 (1972).
41. G. N. Nenaidenko et al., Khimiya v Sel'skom Khozyaistve, 10, 701 (1972).
42. G. N. Nenaidenko et al., Khimiya v Sel'skom Khozyaistve, 11, 377 (1973).
43. G. N. Nenaidenko, Khimiya v Sel'skom Khozyaistve, 12, 541 (1974).
44. N. V. Agafonov and E. P. Solovei, Khimiya v Sel'skom Khozyaistve, 12, 464 (1974).
45. A. D. Avetisyan, G. K. Grigoryan, and A. O. Airapetyan, Khimiya v Sel'skom Khozyaistve, 10, 143 (1972).
46. G. N. Atsekhovskii, Khimiya v Sel'skom Khozyaistve, 10, 606 (1972).
47. H. Kuelin, W. Schusten, and J. Jdel, Z. Acker. Pflanzenbau, 138, 1 (1972).
48. C. D. Lindley, PANS, 19, 87 (1973).
49. N. Koaturski, Koop Zemled., 28, No. 3, 21 (1974).
50. M. Andraacik, G. Huska, and P. Lendnar, Pol'nohospodarstvo, 20, No. 1, 3 (1974).
51. P. E. Read, V. L. Herman, and D. A. Heng, HortScience, 9, No. 1, 55 (1974).
52. T. H. Thomas, Sci. Hortic., 24, 158 (1972–73).
53. W. Krause, Grower, 73, 674 (1970).
54. S. K. Mukherji, Cotton Development, 13, No. 1, 27 (1973).
55. S. Singh and K. Singh, Cotton Development, 1, No. 1, 14 (1971).
56. R. J. Weaver, Amer. J. Enol. Vitic., 26, No. 1, 47 (1975).
57. M. Nagao and S. Temura, Agric. Biol. Chem., 35, 1636 (1971).
58. M. Mohin and M. S. Smith, Pestic. Sci., 3, 333 (1972).
59. M. Fewari et al., Biol. Plant., 15, 157 (1973).
60. H. Haruta et al., Agric. Biol. Chem., 36, 881 (1972).
61. H. Haruta et al., Agric. Biol. Chem., 38, 141 (1974).
62. M. M. El-Fouly et al., Agrochimica, 14, 321 (1970).
63. J. Jung and Z. Acker, Pflanzenbau, 131, 325 (1970).
64. B. Zeeh, K.-H. König, and J. Jung, Kem-Kemi, 1, 621 (1974).
65. J. Jung, H. Sturm, and W. Zwick, Landwirt. Forsch., 24, Sonderheft 28, 46 (1973).
66. K. Nakanishi et al., Japanese P. 50–1029 (1975); Ref. Zhur. Khim., 230 416 (1975).
67. K. Nakanishi et al., Japanese P. 50–1031 (1975); Ref. Zhur. Khim., 230 417 (1975).
68. H. Taylor et al., US P. 3 868 244 (1975).
69. K. Nakanishi et al., Japanese P. 50–1030 (1975); Ref. Zhur. Khim., 220 333 (1975).
70. K. Nakanishi et al., Japanese P. 49–48944 (1974); Ref. Zhur. Khim., 210 349 (1975).
71. H. Tsuchiya et al., US P. 3 856 850 (1974).
72. K. Nakanishi et al., Japanese P. 49–48429 (1970); Ref. Zhur. Khim., 190 435 (1975).
73. W. W. Abramitis, US P. 3 460 936 (1969).
74. K. Nakanishi et al., Japanese P. 50–1025 (1975); Ref. Zhur. Khim., 10467 (1976).
75. K. Nakanishi et al., Japanese P. 50–1027 (1975); Ref. Zhur. Khim., 10468 (1976).
76. K. Nakanishi et al., Japanese P. 50–1028 (1975); Ref. Zhur. Khim., 10474 (1976).
77. S. Tamura et al., Japanese P. 50–2012 (1975); Ref. Zhur. Khim., 10471 (1976).
78. M. Nagao et al., US P. 3 864 349 (1975).
79. S. Basuo*† and Y. Kiguchi*, Japanese P. 50–2902 (1975); Ref. Zhur. Khim., 10469 (1976).
80. N. N. Mel'nikov, Khimiya v Sel'skom Khozyaistve, 13, 900 (1975).
81. G. Skylakakis et al., "Mezhdunarodnyi Kongress po Zashchite Rastenii, Doklady i Soobshcheniya Sektsii III, Khimicheskii Metod Bor'by" (The 8th International Congress on Plant Protection. Reports and Communications of Section III. Chemical Protecting Agents), Moscow, 1975, p. 543.
82. J. Gramlich et al., "Mezhdunarodnyi Kongress po Zashchite Rastenii, Doklady i Soobshcheniya Sektsii III, Khimicheskii Metod Bor'by" (The 8th International Congress on Plant Protection. Reports and Communications of Section III. Chemical Protecting Agents), Moscow, 1975, p. 150.

† Here and henceforth the spelling of authors' names marked with an asterisk is tentative (Ed. of Translation).

83. P. L. Strong et al., US P. 3 764 624 (1973).
84. P. Langelüddeke et al., BRD Appl. 2 258 631 (1974); Ref. Zhur. Khim., 90445 (1975).
85. P. L. Strong et al., US P. 3 829 308 (1974).
86. B. Cross and W. H. Gastruck, US P. 3 844 762 (1974).
87. Q. Soper, BRD P. 1 643 313 (1975).
88. G. Skylakakis et al., see Ref. 10, Vol. 2, p. 795.
89. Sin Khoyaku [?], **28**, No. 2, 29 (1974); Ref. Zhur. Khim., 10455 (1976).
90. M. Wilcox, US P. 3 867 452 (1975).
91. J. F. Olin, US P. 3 830 829 (1974).
92. J. F. Olin, US P. 3 832 383 (1974).
93. K. W. Ratts, US P. 3 830 841 (1974).
94. J. K. Tournayre and C. Vogel, Swiss P. 551 138 (1974).
95. K. Akiba et al., US P. 3 780 090 (1971).
96. H. Moser, DDR P. 111 784 (1975).
97. B. Schiewald et al., DDR P. 109 979 (1974).
98. C. M. Menzie, "Metabolism of Pesticides", Special Scientific Report, Wildlife No. 184, Washington, D. C. 1974, p. 486.
99. L. Maravetz, US P. 3 819 661 (1974).
100. Z. A. Metlitskii, M. N. Gyska, and G. N. Toropova, Symposium, "Primenenie Fiziologicheski Aktivnykh Soedinenii v Sadovodstve" (The Applications of Physiologically Active Compounds in Fruit Farming), Izd. Kolos, Moscow, 1972, p. 128.
101. E. K. Peterson and K. K. Spolitis, Symposium, "Regulyatsiya Rosta i Pitaniya Rastenii" (Regulation of Plant Growth and Nutrition), Minsk, 1972, p. 138.
102. G. E. Stembridge and C. E. Cambrelle, HortScience, 9, No. 1, 29 (1974).
103. S. Stoyanov, Tidsskr. Planteavl., 77, 180 (1973).
104. H. A. Robitalle and G. Janick, HortScience, 8, 316 (1973).
105. G. J. Tehrani, J. Amer. Soc. Hortic. Sci., 98, 468 (1973).
106. L. B. Fitch and G. S. Sibbett, Calif. Agric., 27, 12 (1973).
107. P. H. Jerie, Austral. J. Agric. Res., 24, 91 (1973).
108. W. Perreye, Rev. Agric. (Brussels), 25, 1199 (1972).
109. S. Sansavini, J. Martin, and K. Ryugo, J. Amer. Soc. Hortic. Sci., 95, 708 (1970).
110. W. Williams, Wash. Fruit Grower., 24, No. 2, 8 (1970).
111. M. H. Chaplin and A. L. Kenworthy, J. Amer. Soc. Hortic. Sci., 95, 532 (1970).
112. G. C. Martin and W. H. Griggs, HortScience, 5, 258 (1970).
113. D. R. McCaskill, G. R. Morris, and J. W. Fleming, Arkansas Farm Res., 21, No. 3, 9 (1972).
114. P. W. Dyson, J. Hortic. Sci., 47, 215 (1972).
115. J. C. Hormann, Ghana J. Sci., 12, No. 1, 51 (1972).
116. F. Rylski, Israel J. Agric. Res., 22, No. 1, 31 (1972).
117. P. E. Read and D. J. Fieldhouk, J. Amer. Soc. Hortic. Sci., 95, 73 (1970).
118. F. W. Calder, W. D. Canham, and D. S. Fenson, Canad. J. Plant. Sci., 53, 269 (1973).
119. D. R. Tompkins, R. A. Norton, and C. G. Woldbridge, J. Amer. Soc. Hortic. Sci., 97, 772 (1972).
120. P. Spigel, HortScience, 9, 116 (1974).
121. R. Bastidas and G. L. Buitrago, Acta Agron. (Colomb.), **22**, No. 1, 25 (1972).
122. G. Clapp, Agron. J., 65, No. 1, 41 (1973).
123. V. Q. Hale, Crop. Sci., 11, 678 (1971).
124. B. W. Hipp and W. R. Cowley, J. Amer. Soc. Hortic. Sci., 94, 269 (1969).
125. A. H. Freitag and E. A. Coleman, Agron. J., 65, 610 (1973).
126. A. Busschots, Meded. Rijkstac. Landbouwwetensch. (Gent.), 34, 474 (1969).
127. C. Depauw, Meded. Rijkstac. Landbouwwetensch. (Gent.), 36, 1270 (1971).
128. C. Vanderhoven et al., Meded. Rijkstav. Landbouwwetensch. (Gent.), 37, 623 (1972).
129. D. I. Chkanikov and M. S. Sokolov, "Gerbitsidnoe Deistvie 2,4-D i Drugikh Galoidfenoksikislot" (The Herbicidal Activity of 2,4-D and Other Halogenophenoxy Acids), Izd. Nauka, Moscow, 1973.
130. J. Ristici, Bul. Stiint. Teh. Inst. Politeh. Timisoara, Ser. Chim., 19, 229 (1974).
131. J. Arct and Z. Eckstein, Przemysl. Chem., 54, 335 (1975); Ref. Zhur. Khim., 10457 (1976).
132. A. Sultankulov and A. Khikmatov et al., USSR P. 395 055 (1973); Ref. Zhur. Khim., 22N678 (1974).
133. R. Nishiyama et al., Japanese P. 49-6102 (1974); Ref. Zhur. Khim., 23N658 (1974).
134. R. Puttner and F. Arndt, BRD Appl. 2 234 817 (1974); Ref. Zhur. Khim., 23N660 (1974).
135. A. Fujiami, A. Mine, and T. Fujite, Agric. Biol. Chem., 38, 1399 (1974).
136. K. Mukai et al., Japanese P. 49-28978 (1974); Ref. Zhur. Khim., 80397 (1975).
137. F. Edamura et al., US P. 3 829 489 (1974).
138. L. Nüblein and F. Arndt, BRD Appl. 2 262 402 (1947); Ref. Zhur. Khim., 120 503 (1975).
139. Yu. K. Shcheglov, L. A. Kalutskii, and N. K. Bliznyuk, USSR P. 254 946 (1970); Ref. Zhur. Khim., 130 485 (1975).
140. Sh. Mamedov et al., USSR P. 426 637 (1974); Ref. Zhur. Khim., 200 377 (1975).
141. C. Soderquist and D. Crosby, Pestic. Sci., 6, 17 (1975).
142. J. Kisikawa et al., Japanese P. 2068 (1965); Ref. Zhur. Khim., 200 364 (1975).
143. F. Y. Edamura et al., US P. 3 862 974 (1975).
144. J. R. Beck, BRD Appl. 2 344 521 (1975); Ref. Zhur. Khim., 220 353 (1975).
145. H. Tilles et al., US P. 3 480 671 (1969).
146. Weed Sci., 23, 253 (1975).
147. E. H. Blair, "Chlorodioxins-Origin and Fate", Amer. Chem. Soc., Washington, D. C., 1973, p. 141.
148. M. Kuda* and M. Nagatomi*, Japanese P. 49-21055 (1974); Ref. Zhur. Khim., 200 344 (1975).
149. C. Weis and H. Fischer, Swiss P. 558 321 (1975).
150. G. Mohr et al., BRD P. 1 542 960 (1974).
151. G. Mohr et al., DDR P. 55176 (1967).
152. P. F. Waring, B. P. 1 103 000 (1968).
153. G. Mohr et al., DDR P. 55175 (1967).
154. D. Cachita et al., Romanian P. 56308 (1974); Ref. Zhur. Khim., 210 385 (1975).
155. S. Kinoshita and M. Mukai, USSR P. 199 782 (1967); Ref. Zhur. Khim., 200 375 (1975).
156. J. Berger et al., US P. 3 869 277 (1975).
157. B. Mrva et al., B. P. 149 008 (1973).
158. G. K. Rudnev, I. G. Khaskin, B. A. Geller, and V. E. Davidkovskii, "Khimicheskaya Tekhnologiya. Nauchno-proizv. Sbornik" (Chemical Engineering. Scientific and Industrial Symposium), Izd. Naukova Dumka, 1975, No. 3, p. 19.
159. A. Kudamatsu et al., US P. 3 852 318 (1974).
160. K. Payne and P. Haggett, B. P. 1 372 521 (1974).
161. G. Batchelor, US P. 3 443 928 (1969).
162. E. Lacroyx and S. Duke, B. P. 1 380 438 (1975).
163. C. Hoffman, US P. 3 852 058 (1974).
164. B. Werner et al., BRD Appl. 2 223 894 (1972); Ref. Zhur. Khim., 22N670 (1974).

165. O.Yamada et al., Japanese P.49-11418 (1974); Ref.Zhur.Khim., 22N669 (1974).
166. H.Kurono et al., Japanese P.14818 (1967); Ref. Zhur.Khim., 230425 (1975).
167. C.P.Griffiths and C.T.Lake, Proceedings 11th British Weed Control Conference, Brighton, 1, 138 (1972).
168. B.J.VanDen Brink, D.J.Bracey, and R.A.Gray, Proceedings 3rd Symposium on New Herbicides, 1, 35 (1969).
169. J.B.Miaullis and R.A.Gray, Weed Abstr., 24, 2829 (1975).
170. K.Luerssen, K.Metuger*, and G.Eger*, "VIII Mezhdunarodnyi Kongress po Zashchite Rastenii, Doklady i Soobshcheniya Sektsii III" (The 8th International Congress on Plant Protection, Reports and Communications in Section III), Moscow, 1975, p.403.
171. F.Arndt and G.Boroschewski, "VIII Mezhdunarodnyi Kongress po Zashchite Rastenii, Doklady i Soobshcheniya Sektsii III" (The 8th International Congress on Plant Protection, Reports and Communications in Section III), Moscow, 1975, p.40.
172. F.Y.Edamura and T.J.Giacobbe, US P.3790619 (1974).
173. C.Emersen and R.Aichennegg, US P.3784563 (1974).
174. Z.Vesela et al., Czech P.148794 (1973); Ref. Zhur.Khim., 210365 (1975).
175. K.Nakanishi et al., Japanese P.49-11064 (1974); Ref.Zhur.Khim., 23N698 (1974).
176. A.Fischer et al., US P.3810751 (1974).
177. P.Montijn and E.Haddock, B.P.1355349 (1974).
178. G.Kornis and E.Nidy, US P.3829463 (1974).
179. J.E.Frans, US P.3836572 (1974).
180. R.Puttner and F.Arndt, BRD Appl.2234816 (1974); Ref.Zhur.Khim., 23N659 (1974).
181. Yu.A.Baskakov, in "Mekhanizm Deistviya Gerbitsidov" (The Mechanism of the Action of Herbicides), Izd.Bolg.Akad.Nauk, Sofiya, 1975.
182. B.Gross and C.P.Grasso, US P.3867429 (1975).
183. J.F.Olin and P.C.Hamm, US P.3867426 (1975).
184. G.Boroschewski and F.Arndt, BRD Appl.2341079 (1975); Ref.Zhur.Khim., 10480 (1976).
185. G.Gras, French P.2210186 (1974).
186. M.Wilcox, US P.3869278 (1975).
187. G.Boroschewski et al., BRD P.1567151 (1974).
188. G.Gras, French P.2182242 (1973).
189. K.P.Dorschner and J.A.Albright, US P.3806537 (1974).
190. G.Kornis and E.Nidy, US P.3829463 (1974).
191. G.Boroschewski et al., BRD P.1593520 (1974).
192. E.E.Schweizer, Weed Abstr., 24, 2938 (1975).
193. G.Boroschewski and F.Arndt, BRD Appl.2310648 (1974); Ref.Zhur.Khim., 110486 (1975).
194. C.Arens, C.Gates, and H.Laufresweiler, Weed Abstr., 24, 2940 (1975).
195. N.I.Faddeeva and Yu.A.Baskakov, USSR P.239966 (1969); Ref.Zhur.Khim., 120504 (1975).
196. K.Sasse et al., BRD Appl.2317367 (1974); Ref. Zhur.Khim., 150499 (1975).
197. R.Fraley, US P.3874939 (1975).
198. French P.1471952 (1967).
199. K.Carpenter et al., US P.3823008 (1974).
200. A.Fischer, US P.3870502 (1975).
201. G.H.Singhal and R.E.Turkos, US P.3776936 (1973).
202. J.J.D'Amico and M.W.Harman, US P.3305576 (1967); French P.1514270 (1968); Swedish P. 210849 (1967).
203. H.Pitt, US P.3836524 (1974).
204. A.Fischer et al., BRD P.2329043 (1975).
205. I.Kimura et al., US P.3816500 (1974).
206. M.Kannai et al., US P.3822124 (1974).
207. M.Itibashi* et al., Japanese P.49-10743 (1974); Ref.Zhur.Khim., 23N679 (1974).
208. I.Kimura et al., Japanese P.49-16935 (1974); Ref.Zhur.Khim., 24N701 (1974).
209. H.Ayamasa* [M.Aya ?] et al., Japanese P.49-39816 (1974); Ref.Zhur.Khim., 160498 (1975).
210. A.Kudamatsu et al., US P.3846467 (1968).
211. M.Kannai et al., US P.3846115 (1974).
212. G.Losco and A.Quattrini, French Appl.2209753 (1974); Ref.Zhur.Khim., 160487 (1975).
213. K.Vakamori* et al., Japanese P.49-35978 (1974); Ref.Zhur.Khim., 150497 (1975).
214. W.Töpfi, Swiss P.555817 (1974).
215. M.Aya et al., Japanese P.49-27875 (1974); Ref. Zhur.Khim., 160483 (1975).
216. H.Ayamasa* [M.Aya ?] et al., Japanese P.49-35147 (1974); Ref.Zhur.Khim., 160483 (1975).
217. M.Aya et al., US P.3813405 (1970).
218. M.Aya et al., Japanese P.49-44329 (1974); Ref. Zhur.Khim., 220359 (1975).
219. F.Walker, US P.3816435 (1974).
220. A.Fischer et al., BRD Appl.2312045 (1974); Ref. Zhur.Khim., 140526 (1975).
221. A.Fischer et al., BRD Appl.2333397 (1975); Ref. Zhur.Khim., 190456 (1975).
222. V.Karadini*, A.Helmetti*, and K.Lasagna*, "VIII Mezhdunarodnyi Kongress po Zashchite Rastenii, Doklady i Soobshcheniya Sektsii III" (The 8th International Congress on Plant Protection. Reports and Communications in Section III), Moscow, 1975, Vol.1, p.305.
223. F.Gozzo et al., "VIII Mezhdunarodnyi Kongress po Zashchite Rastenii, Doklady i Soobshcheniya Sektsii III" (The 8th International Congress on Plant Protection. Reports and Communications in Section III), Moscow, 1975, Vol.1, p.141.
224. P.Langelüddeke and E.F.Schulze, Proceedings 11th British Weed Control Conference, 2, 830 (1972).
225. R.J.Marrese, Proceedings 11th British Weed Control Conference, 2, 835 (1972).
226. K.R.Hubbard and D.B.Livingston, Proceedings 12th British Weed Control Conference, 1, 67 (1974).
227. R.T.Hewson, Proceedings 12th British Weed Control Conference, 1, 75 (1974).
228. E.L.Ummel et al., Proceedings 12th British Weed Control Conference, 1, 83 (1974).
229. L.Burgaud et al., Proceedings 12th British Weed Control Conference, 2, 801 (1974).
230. L.G.Copping and R.F.Brookes, Proceedings 12th British Weed Control Conference, 2, 809 (1974).
231. J.Desmoras, D.Ambrosi, and R.Boesch, "VIII Mezhdunarodnyi Kongress po Zashchite Rastenii, Doklady i Soobshcheniya Sektsii III" (The 8th International Congress on Plant Protection. Reports and Communications in Section III), Moscow, 1975, p.184.
232. E.Kuehle, E.Klauke, and L.Eue, "VIII Mezhdunarodnyi Kongress po Zashchite Rastenii, Doklady i Soobshcheniya Sektsii III" (The 8th International Congress on Plant Protection. Reports and Communications in Section III), Moscow, 1975, p.356.
233. F.Schverdle* and H.Schumacher*, "VIII Mezhdunarodnyi Kongress po Zashchite Rastenii, Doklady i Soobshcheniya Sektsii III" (The 8th International

Congress on Plant Protection. Reports and Communications in Section III), Moscow, 1975, Vol. 2, p. 654.
234. M. Schuler, US P. 3 865 571 (1975).
235. H. Martin et al., US P. 3 864 395 (1975).
236. J. Krenzer and S. Richter, US P. 3 864 377 (1975).
237. C. Mezger et al., BRD Appl. 2 340 570 (1975); Ref. Zhur. Khim., 200 371 (1975).
238. V. Konecny, Czech P. 151 232 (1973); Ref. Zhur. Khim., 180 444 (1975).
239. O. Scherer et al., BRD P. 1 568 641 (1974).
240. E. Teach, US P. 3 852 348 (1974).
241. D. Dürr, Swiss P. 558 141 (1975).
242. V. Kato and M. Kado, US P. 3 849 109 (1974).
243. J. Platz, US P. 3 850 986 (1974).
244. R. Thomas et al., BRD Appl. 2 247 310 (1974); Ref. Zhur. Khim., 150 500 (1975).
245. O. Scherer et al., BRD P. 1 668 110 (1974).
246. A. Terakawa et al., Japanese P. 49–28504 (1974), Ref. Zhur. Khim., 90451 (1975).
247. P. Held et al., DDR P. 100 142 (1973).
248. F. Eder, Swiss P. 548 158 (1974).
249. D. Showa, BRD Appl. 2 166 739 (1973); Ref. Zhur. Khim., 22N675 (1974).
250. T. Fridinger et al., US P. 3 817 740 (1974).
251. G. Barbaras et al., US P. 3 297 425 (1967).
252. C. Weis and J. Rumpf, Czech. P. 146 796 (1972); Ref. Zhur. Khim., 210 398 (1975).
253. T. Takematsu et al., USSR P. 352 433 (1973); Ref. Zhur. Khim., 170 396 (1975).
254. Austr. P. 138 939 (1973); Ref. Zhur. Khim., 120 515 (1975).
255. A. Fischer et al., BRD P. 1 221 841 (1967).
256. Polish P. 68292 (1973); Ref. Zhur. Khim., 22N663 (1974).
257. J. Chupp, US P. 3 761 241 (1973).
258. E. Kühle et al., BRD Appl. 2 234 586 (1974); Ref. Zhur. Khim., 23N666 (1974).
259. W. Pyne et al., BRD P. 2 039 908 (1974).
260. H. Ayamasa* [M. Aya ?] et al., Japanese P. 49–35982 (1974); Ref. Zhur. Khim., 150 505 (1975).
261. Austr. P. 315 571 (1974); Ref. Zhur. Khim., 70359 (1975).
262. J. D. Cleveland, US P. 3 857 883 (1974).
263. M. Brown, US P. 3 853 966 (1974).
264. K. Tatesa* et al., Japanese P. 49–37246 (1974); Ref. Zhur. Khim., 160 480 (1975).
265. M. Brown, US P. 3 771 993 (1973).
266. M. Brown, US P. 3 824 281 (1974).
267. A. Micailovski, US P. 3 829 307 (1974).
268. W. Töpfl, Swiss P. 547 288 (1974).
269. E. Teach, US P. 3 781 305 (1973).
270. W. Wah, US P. 3 859 301 (1975).
271. L. Näsself and F. Arndt, BRD Appl. 2 341 816 (1975); Ref. Zhur. Khim., 240 556 (1975).
272. T. Cebalo and R. Walde, Swedish P. 369 191 (1974).
273. J. Krenzer, US P. 3 864 775 (1975).
274. A. Micailovsky, US P. 3 860 410 (1975).
275. L. Maravetz, US P. 3 859 313 (1975).
276. F. Arndt and L. Nüsslein, BRD Appl. 2 360 709 (1975); Ref. Zhur. Khim., 230 435 (1975).
277. T. Noguti et al., USSR P. 383 237 (1973); Ref. Zhur. Khim., 170 414 (1975).
278. K. Sasse et al., BRD Appl. 2 320 362 (1974); Ref. Zhur. Khim., 150 509 (1975).
279. L. Nüsslein et al., BRD Appl. 2 246 461 (1974); Ref. Zhur. Khim., 150 510 (1975).
280. C. Metzger et al., BRD P. 1 817 949 (1974).
281. C. Metzger et al., BRD Appl. 2 303 079 (1974); Ref. Zhur. Khim., 110 494 (1975).
282. T. Gebalo and R. Walde, Swiss P. 554 886 (1974).
283. J. Guillot and P. Poignant, US P. 3 821 239 (1974).
284. B. P. 1 355 513 (1974).
285. H. Grabinger and R. Schring, BRD P. 1 670 172 (1974).
286. A. Miller, Austr. P. 311 116 (1973); Ref. Zhur. Khim., 70364 (1975).
287. H. Moser and C. Vogel, Swiss P. 549 338 (1974).
288. G. Volpp and H. Dounchis, US P. 3 787 434 (1974).
289. C. W. Hogue, Weed Sci., **22**, 97 (1974).
290. N. N. Mel'nikov, Yu. A. Baskakov and M. E. Kuperman, Trudy NIUIF, **158**, 266 (1958).
291. C. A. Edwards (Editor), "Environmental Pollution by Pesticides", Plenum Press, London–New York, 1973, p. 542.
292. S. A. Lowance, E. J. Peters, and R. E. Mattas, Weed Sci., **23**, 222 (1975).
293. R. S. Campbell and J. K. Greig, HortScience, **9**, 71 (1974).
294. D. R. Tompkins et al., Arkansas Farm Res., **21**, No. 3, 8 (1972).
295. D. R. Tompkins et al., HortScience, **6**, 393 (1971).
296. C. A. Stuthe and R. D. Rudolf, Arkansas Farm Res., **20**, No. 2, 16 (1971).
297. C. A. Stuthe and R. D. Rudolf, Arkansas Farm Res., **22**, No. 3, 2 (1973).
298. N. F. Zubkova et al., Khimiya v Sel'skom Khozyaistve, **12**, 385 (1974).
299. C. D. McCarty and M. P. Miller, Calif. Agric., **27**, No. 1, 3 (1973).
300. L. Ferte and J. Pecherr, Phytiat.-Phytopharm., **10**, No. 3, 113 (1970).
301. R. C. DeWilde, HortScience, **6**, 364 (1971).
302. A. Chrominski and B. Bozej, Acta Agron. Acad. Sci. Hung., **22**, 27 (1973).
303. M. Day and D. A. Jones, Commerc. Grower., No. 4027, 505 (1973).
304. N. D. Bondad and E. B. Pantastico, Econ. Bot., **26**, 238 (1972).
305. M. Pobbins and R. E. Peterson, Hortic. Res., **12**, 141 (1972).
306. J. P. Ashby, Hortic. Res., **18**, 145 (1972).
307. J. P. Ashby and H. A. Waterson, Hortic. Res., **12**, 201 (1972).
308. W. T. Bussell, N. Z. J. Exp. Agric., **1**, 123 (1973).
309. J. A. Weliath and A. C. Ferguson, J. Amer. Soc. Hortic. Sci., **98**, 124 (1973).
310. R. Young et al., HortScience, **5**, 268 (1970).
311. L. Jath, J. Amer. Soc. Hortic. Sci., **98**, 230 (1973).
312. G. R. Stino, D. Donchev, and A. Petrov, Dokl. Sel'skokhoz. Akad. NRB, **5**, 109 (1972).
313. D. R. Tompkins and D. F. Schulteis, Arkansas Farm. Res., **19**, No. 6, 5 (1970).
314. C. H. Mikler and R. L. Lower, HortScience, **7**, 418 (1972).
315. E. J. Hogue and H. B. Hechey, HortScience, **9**, 72 (1974).
316. D. Levy et al., HortScience, **7**, 470 (1972).
317. C. R. Blatt and A. G. Sponagle, Canad. J. Plant Sci., **53**, 585 (1973).
318. H. B. Legersedt, J. Amer. Soc. Hortic. Sci., **97**, 738 (1972).
319. W. K. Baily and J. E. Bear, J. Amer. Peanut Res. Educ. Ass., **5**, No. 1, 20 (1973).
320. D. Cuele, Fruit Grower., **25**, No. 5, 6 (1971).
321. G. Martin, J. Amer. Soc. Hortic. Sci., **96**, 431 (1971).
322. T. Georgiev and P. Uzunov, Sel'skostop. Tekh. NRB, **10**, No. 4, 85 (1973).

323. T. Georgiev and P. Uzunov, Sel'skostop. Tekh. NRB, 10, No. 4, 85 (1973).
324. D. Gremashi, Tobacco, 76, No. 745, 19 (1972).
325. R. Ronald and C. Vogel, US P. 3 808 265 (1974).
326. W. Kochmann et al., DDR P. 105 117 (1974).
327. F. Freenor, US P. 3 794 699 (1974).
328. H. Ayamasa* [M. Aya ?] et al., Japanese P. 49-28979 (1974); Ref. Zhur. Khim., 60404 (1975).
329. R. Theissen, US P. 3 826 640 (1974).
330. H. Kleiner, BRD Appl. 2 259 241 (1974); Ref. Zhur. Khim., 90469 (1975).
331. E. Beriger, Swiss P. 549 334 (1974).
332. P. Beutel et al., BRD Appl. 2 249 939 (1974); Ref. Zhur. Khim., 100 478 (1975).
333. G. Schrader et al., US P. 3 823 004 (1974).
334. P. Epstein et al., US P. 3 819 357 (1974).
335. W. Toepfi, US P. 3 833 600 (1974).
336. W. Langsdorf, US P. 3 819 353 (1974).
337. D. Randall and R. Wynn, US P. 3 838 180 (1974).
338. V. P. Rudavskii, M. N. Kucherova, and D. F. Shirankov, "Fiziologicheski Aktivnye Veshchestve, Respublikanskii Mezhvedomstvennyi Sbornik" (Physiologically Active Substances. The Republican Interdepartmental Symposium), Izd. Naukova Dumka, Kiev, 1975, Vol. 7, p. 27.
339. R. Schring et al., BRD Appl. 2 320 371 (1974); Ref. Zhur. Khim., 140 524 (1975).
340. G. Syuradel* et al., Japanese P. 49-42504 (1974); Ref. Zhur. Khim., 150 504 (1975).
341. H. Bucha and W. Langsdorf, US P. 3 849 102 (1974).
342. U. Suwunnamek and C. Parker, Weed Res., 15, 13 (1975).
343. Belgian P. 743 863 (1973).
344. G. Schrader et al., US P. 3 796 560 (1974).
345. E. Sturm and H. Cellarius, Swiss P. 559 214 (1975).
346. H. Schult and W. Schwarce, DDR P. 43614 (1966).
347. L. Fancher and C. Dewald, US P. 3 298 819 (1967).
348. E. Regel, US P. 3 294 876 (1966).
349. E. Beriger, Swiss P. 485 414 (1970).
350. E. Regel, US P. 3 385 688 (1968).
351. S. Richter, US P. 3 385 689 (1968).
352. G. Schrader et al., US P. 3 473 920 (1969).
353. D. Turner and M. Loader, Pestic. Sci., 6, 1 (1975).
354. I. M. Azerbaev et al., USSR P. 257 219 (1970); Ref. Zhur. Khim., 210 378 (1975).
355. E. Regel and M. Botts, US P. 3 481 731 (1969).
356. R. Cöllin and K. Lürssen, BRD Appl. 2 331 187 (1975); Ref. Zhur. Khim., 210 375 (1975).
357. R. Moll et al., DDR P. 101 281 (1973).
358. J. Franz, US P. 3 853 530 (1974).
359. P. Rodewald et al., US P. 3 773 791 (1973).
360. K. Ratts, US P. 3 776 984 (1973).
361. W. Hofer et al., US P. 3 771 992 (1973).
362. J. Wagenknecht, US P. 3 859 183 (1975).
363. F. Franz and H. Nufer, US P. 3 868 407 (1975).
364. E. Günther et al., DDR P. 94280 (1972).
365. P. Epstein, US P. 3 847 947 (1974).
366. I. N. Azerbaev et al., USSR P. 399 229 (1974); Ref. Zhur. Khim., 24N712 (1974).
367. S. Kisino and T. Kume, Japanese P. 49-36228 (1974); Ref. Zhur. Khim., 120 511 (1975).
368. K. Satomi* et al., Japanese P. 49-48502 (1974); Ref. Zhur. Khim., 240 547 (1975).
369. W. Föry et al., Swiss P. 550 536 (1974).
370. K. Mukai et al., Japanese P. 49-28978 (1974); Ref. Zhur. Khim., 80397 (1975).
371. J. E. Franz, US P. 3 799 758 (1974).
372. R. Haque and V. H. Freed (Editors), "Environmental Dynamics of Pesticides", Plenum Press, New York-London, 1975, p. 387.
373. D. Randal et al., US P. 3 787 486 (1974).
374. G. Syuradel'* et al., Japanese P. 49-42503 (1974); Ref. Zhur. Khim., 160 477 (1975).
375. M. Aya et al., US P. 3 819 754 (1974).
376. A. F. Grapov, N. V. Lebedeva, N. N. Mel'nikov, T. A. Sergeeva, L. D. Stonov, L. M. Titova, and E. N. Volkotrub, Agrokhimiya, No. 1, 96 (1972).
377. A. F. Vasil'ev, G. F. Tulyakova, N. N. Mel'nikov, A. F. Grapov, and T. F. Kozlova, in "Khimiya i Primenenie Fosfororganicheskikh Soedinenii" (The Chemistry and Applications of Organophosphorus Compounds), Izd. Nauka, 1974, p. 390.
378. N. N. Mel'nikov, "Doklady na Sektsiyakh VIII Mezhdunarodnogo Kongressa po Zashchite Rastenii" (Abstracts of Reports in the Sections of the 8th International Congress on Plant Protection), Moscow, 1975, Vol. 2, p. 107.
379. L. D. Stonov, "Doklady na Sektsiyakh VIII Mezhdunarodnogo Kongressa po Zashchite Rastenii" (Abstracts of Reports in the Sections of the 8th International Congress on Plant Protection), Moscow, 1975, Vol. 2, p. 150.
380. M. Aya et al., US P. 3 882 202 (1975).
381. A. F. Grapov et al., USSR P. 407 552 (1973); Byul Izobret., No. 47 (1973); Ref. Zhur. Khim., 100 483 (1975).
382. M. H. Niehus and K. J. Roediger, Proceedings 12th British Weed Control Conference, 3, 1015 (1974).
383. M. I. Kabachnik, Izv. Akad. Nauk SSSR, Otd. Khim. Nauk, 295, 403, 515 (1946); 95 (1948).
384. T. Ozaki et al., Japanese P. 50-9708 (1975); Ref. Zhur. Khim., 10483 (1976).
385. W. Föry et al., Swiss P. 561 731 (1975).
386. K. Pilgram et al., US P. 3 876 678 (1975).
387. N. Stoskopf and J. Law, Canad. J. Plant Sci., 52, 680 (1972).
388. Farm. Chem., 135, No. 12, 54 (1972).
389. N. N. Mel'nikov, E. G. Novikov, and B. A. Khaskin, "Khimiya i Biologicheskaya Aktivnost' Dipiridilov i Ikh Proizvodnykh" (The Chemistry and Biological Activity of Bipyridyls and Their Derivatives), Izd. Khimiya, Moscow, 1975, p. 104.
390. A. Waters et al., B. P. 1 395 502 (1975).
391. Yu. V. Rakitin (Editor), Symposium, "Gidrazid Maleinovoi Kisloty kak Regulyator Rosta Rastenii" (Maleic Acid Hydrazide as a Plant Growth Regulator), Izd. Nauka, Moscow, 1973.
392. C. Barlow et al., B. P. 1 363 415 (1974).
393. L. Markley, US P. 3 862 952 (1975).
394. L. Levine, US P. 3 475 441 (1969).
395. R. Diehl and B. Walwoth, US P. 3 826 643 (1974).
396. R. Noveroske, US P. 3 856 502 (1974).
397. R. Bimber, US P. 3 325 503 (1967).
398. R. Whitaker and H. Smith, US P. 3 814 774 (1974).
399. R. Rowden and T. Seaton, B. P. 1 344 336 (1974).
400. R. Noveroske, US P. 3 820 973 (1974).
401. C. Tomlin et al., B. P. 1 059 990 (1967).
402. R. Bowden and R. Slater, B. P. 1 367 383 (1974).
403. Yu. V. Karabanov, A. F. Pavlenko, V. P. Borisenko, S. D. Moshchitskii, N. G. Zemlyakova, V. P. Akkerman, and Ya. N. Ivashchenko, "Fiziologicheski Aktivnye Veshchestva. Respublikanskii Mezhvedomstvennyi Sbornik" (Physiologically Active Substances. Republican Interdepartmental Symposium), 1974, No. 6, p. 18.
404. A. F. Pavlenko, V. P. Akkerman, K. A. Abramova,

D. F. Shirankov, D. S. Moshchinskii, and Ya. N. Ivashchenko, "Fiziologicheski Aktivnye Veshchestva. Respublikanskii Mezhvedomstvennyi Sbornik" (Physiologically Active Substances. Republican Interdepartmental Symposium), 1974, No. 6, p. 77.
405. H. Johnston and S. Raetman, US P. 3 686 198 (1972).
406. R. Martin et al., Dutch P. 127 349 (1970).
407. C. Barlow et al., B. P. 1 363 415 (1974).
408. E. P. Ugryumov et al., USSR P. 438 403 (1975); Ref. Zhur. Khim., 200 374 (1975).
409. E. P. Ugryumov et al., USSR P. 438 401 (1975); Ref. Zhur. Khim., 20490 (1976).
410. W. Pyne et al., US P. 3 778 247 (1973).
411. A. Crovetti and D. Lynch, US P. 3 816 451 (1974).
412. G. V. Esipov et al., USSR P. 389 766 (1972); Ref. Zhur. Khim., 22N695 (1974).
413. P. Cruickshank, US P. 3 773 491 (1973).
414. P. Gates et al., US P. 3 689 507 (1972).
415. W. L. Elins and C. H. Cronion, J. Amer. Soc. Sugar Beet Technol., 17, 134 (1972).
416. W. Kollmeyer and K. Pilgram, US P. 3 746 704 (1973).
417. M. Singer, US P. 3 854 925 (1974).
418. Ch. Sh. Kadyrov et al., USSR P. 413 928 (1974); Ref. Zhur. Khim., 80411 (1975).
419. V. P. Borisenko, V. N. Gridagova, L. S. Kudinova, V. I. Rudyk, and V. I. Troitskaya, "Fiziologicheski Aktivnye Veshchestva. Respublikanskii Mezhvedomstvennyi Sbornik" (Physiologically Active Substances. Republican Interdepartmental Symposium), 1975, No. 7, p. 31.
420. H. Goldsmith and R. Crawford, US P. 3 317 554 (1967).
421. T. Iwata et al., Japanese P. 50–2013 (1975); Ref. Zhur. Khim., 10495 (1976).
422. A. Crovetti et al., US P. 3 869 274 (1975).
423. W. Perkow, BRD Appl. 2 261 431 (1974); Ref. Zhur. Khim., 80400 (1975).
424. R. Feeny, US P. 3 857 692 (1974).
425. R. Feeny, US P. 3 867 403 (1975).
426. K. Dorschner and J. Albright, US P. 3 859 292 (1975).
427. S. Strycker and D. Wysong, US P. 3 888 219 (1974).
428. A. Litt and J. Englehart, US P. 3 780 051 (1973).
429. K. Sasse et al., BRD Appl. 2 344 134 (1975); Ref. Zhur. Khim., 220 365 (1975).
430. G. Beck et al., BRD Appl. 2 231 097 (1974); Ref. Zhur. Khim., 22N683 (1974).
431. A. Mine et al., US P. 3 846 441 (1974).
432. Yu. A. Baskakov, M. I. Faddeeva, L. A. Bakumenko, V. G. Kazakova, and S. S. Baranova, "Fiziologicheski Aktivnye Veshchestva. Respublikanskii Mezhvedomstvennyi Sbornik" (Physiologically Active Substances. Republican Interdepartmental Symposium), 1975, No. 7, p. 90.
433. K. Kitasaki et al., US P. 3 443 925 (1969).
434. G. Singhal and J. Lesser, US P. 3 780 056 (1973).
435. P. Kirby and R. Turner, Proceedings 12th British Weed Control Conference, **2**, 817 (1974).
436. P. Held et al., DDR P. 104 690 (1974).
437. A. Fischer et al., BRD Appl. 2 351 589 (1975); Ref. Zhur. Khim., 10473 (1976).
438. H. Fischer, Swiss P. 558 137 (1975).
439. D. Davenport et al., USSR P. 379 092 (1973); Ref. Zhur. Khim., 40330 (1975).
440. H. Taylor et al., US P. 3 818 009 (1974).
441. H. Taylor et al., US P. 3 869 456 (1975).
442. K. Büchel et al., BRD P. 1 294 086 (1970).
443. S. Lang et al., DDR P. 109 170 (1974).
444. R. Kupelian, US P. 3 867 126 (1975).
445. R. Schönbeck et al., Austr. P. 320 657 (1975); Ref. Zhur. Khim., 10489 (1976).
446. S. Hillers, L. Avota, and A. Lazdins, USSR P. 436 055 (1974); Ref. Zhur. Khim., 190 463 (1975).
447. R. Schönbeck et al., BRD Appl. 2 331 398 (1975); Ref. Zhur. Khim., 180 465 (1975).
448. R. Splhacek and J. Vano, Czech P. 153 812 (1974); Ref. Zhur. Khim., 180 466 (1975).
449. A. Diskus et al., Austr. P. 319 960 (1975); Ref. Zhur. Khim., 170 410 (1975).
450. S. Tamura et al., Japanese P. 17352 (1967); Ref. Zhur. Khim., 160 495 (1975).
451. R. Aries, French P. 2 196 646 (1974).
452. Y. Takeuchi, Chem. Regulat. Plants, 8, 10 (1973).
453. A. Diskus et al., BRD Appl. 2 229 744 (1974); 2 229 758 (1974); Ref. Zhur. Khim., 24N713, 24N714 (1974).
454. C. Ungvarsky et al., Czech P. 144 495 (1972); Ref. Zhur. Khim., 22N693 (1974).
455. A. Zschock et al., BRD P. 1 670 291 (1974).
456. T. Chapman et al., US P. 3 786 053 (1974).
457. Polish P. 68404 (1973); Ref. Zhur. Khim., 22N688 (1974).
458. R. Wells et al., US P. 3 773 763 (1973).
459. K. Hass and C. Vogel, Swiss P. 547 296 (1974).
460. W. Schwarze, BRD P. 1 670 541 (1973).
461. T. Grauer, BRD P. 1 695 117 (1974).
462. K. Gass and C. Vogel, Swiss P. 549 340 (1974).
463. E. Nikles, US P. 3 799 925 (1974).
464. J. Chakrabarti and A. Todd, B. P. 1 353 581 (1974).
465. L. Bostian, US P. 3 812 120 (1974).
466. M. Brown, US P. 3 817 742 (1974).
467. N. N. Mel'nikov and I. A. Mel'nikova, USSR P. 416 357 (1974); Ref. Zhur. Khim., 110 506 (1975).
468. E. Nikles, Swiss P. 485 408 (1970).
469. D. Berger et al., Swiss P. 559 005 (1975).
470. A. McDonald, US P. 3 856 793 (1974).
471. T. Chapman et al., B. P. 1 362 366 (1974).
472. T. Ikeda and K. Mitsuguti*, Japanese P. 5942 (1966); Ref. Zhur. Khim., 210 395 (1975).
473. I. A. Mel'nikova, Yu. A. Baskakov, and T. S. Zhuravskaya, USSR P. 196 875 (1967); Ref. Zhur. Khim., 210 396 (1975).
474. J. Cleveland, US P. 3 864 342 (1975).
475. T. Grauer, Swiss P. 457 469 (1968).
476. F. Ross and S. Richter, US P. 3 316 264 (1967).
477. W. Draber*, K. Dikore*, and H. Timmler*, "VIII Mezhdunarodnyi Kongress po Zashchite Rastenii, Doklady i Soobshcheniya Sektsii III" (The 8th International Congress on Plant Protection. Reports and Communications in Section III), Moscow, 1975, Vol. 1, p. 203.
478. W. Draber et al., BRD Appl. 2 346 936 (1975); Ref. Zhur. Khim., 10492 (1976).
479. A. Zschocke et al., BRD P. 1 670 291 (1974).
480. H. Schlee et al., BRD Appl. 2 254 200 (1974); Ref. Zhur. Khim., 110 511 (1975).
481. J. Fuchs and J. Wommack, US P. 3 850 924 (1974).
482. M. Jauteat and K. Ley, BRD Appl. 2 165 554 (1973); Ref. Zhur. Khim., 22N690 (1974).
483. A. Fischer et al., BRD Appl. 2 349 114 (1975); Ref. Zhur. Khim., 230 453 (1975).
484. M. El-Hai and B. Dominy, US P. 3 862 191 (1975).
485. C. Metzger et al., BRD Appl. 2 301 703 (1974); Ref. Zhur. Khim., 110 496 (1975).
486. N. Dahle and W. Doyle, US P. 3 808 223 (1974).
487. H. Röchling et al., BRD Appl. 2 332 000 (1975); Ref. Zhur. Khim., 180 464 (1975).

488. J.Krenzer, US P. 3 849 412 (1974).
489. E.George et al., US P. 3 865 570 (1975).
490. T.Cebalo, US P. 3 856 503 (1974).
491. E.George et al., B.P. 1 381 840 (1975).
492. F.Matsumura, "Toxicology of Insecticides", Plenum Press, New York, 1975, p. 503.

All-Union Institute of Chemical Plant Protection Agents, Moscow