MAJOR FACTORS INFLUENCING THE USE OF HERBICIDES ON SHALLOTS (*ALLIUM CEPA* L.) IN NORTHERN CEYLON

Thesis for the Degree of Ph. D.
MICHIGAN STATE UNIVERSITY

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1965

ABSTRACT

MAJOR FACTORS INFLUENCING THE USE OF HERBICIDES ON SHALLOTS (*ALLIUM CEPA* L.) IN NORTHERN CEYLON

by Suppiah Sinnadurai

Field experiments were conducted in Northern Ceylon to determine some of the major factors that influence the use of four commonly used herbicides. The prime factor was whether herbicides could compete with the cheap labour that was available. Herbicides not only reduced the weeding costs but also caused an increase in the yield. CDAA + TCBC at 10 lb/A gave the best results followed by CDAA and CDEC.

It was observed that shallots had to be rested for over sixty-five days from the date of harvest to time of planting if chemicals were to be used for controlling weeds. Herbicides had to be sprayed three to four days after planting; delayed application tended to kill the shoots or inhibit growth. The correct time of application was during

germination of the weed seeds.

Herbicides were more effective under sprinkler irrigation than under flood irrigation. The herbicidal effectiveness was also better with irrigation during the dry season (Yala Season) than during the wet season (Maha Season). Heavy rains during the wet season tended to leach the chemicals and thus reduce their effectiveness. The lack of sufficient sunlight during the Maha Season caused a set-back in the growth of shallots and this gave sufficient time for the weeds to grow and smother the crop. Increase in organic manure application caused an increase in weed population and thus higher dosages of the chemical were required.

a-chloro-N, N-diallylacetamide + trichlorobenzylchloride at 10 lb/A gave the best results under both systems of irrigation. 2-chloroallyl diethyldithiocarbamate and a-chloroallyl-N, N-diallylacetamide showed an apparent increase in the chlorophyll content of leaves (plants were darker green in colour with luxuriant growth) and there was an increase in the bulb weight.

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A THESIS

Submitted to
Michigan State University
in partial fulfillment of the requirements
for the degree of

DOCTOR OF PHILOSOPHY

Department of Botany and Plant Pathology

1965

ACKNOWLEDGEMENTS

The author wishes to express his sincere appreciation to Dr. B. H. Grigsby and Dr. C. J. Pollard for the advice, guidance, and assistance during the preparation of this thesis. Appreciation is also expressed to Prof. Boyd R. Churchill and Dr. S. K. Ries for the guidance in writing this manuscript and to Dr. N. E. Good and Dr. W. B. Drew for serving on the guidance committee.

Special appreciation is due to the Department of Agriculture, Ceylon, for the use of their Experiment Station at Tinnevely, Jaffna, where the field research was conducted.

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INTRODUCTION

Weed control is one of the oldest agricultural practices that is known to man. The methods used in Ceylon in controlling weeds have not undergone any appreciable change. The need to control and eliminate weeds was strongly felt in order to promote the growth of the desirable species. Improved weed control practices have not only increased yields but also have improved the quality of crops.(14)

The control of weed competition in onions has become important in order to improve the size of the bulb and also to obtain higher yields. The close spacing (approximately four inches apart) of shallots, at the time of planting, in Ceylon, does not permit mechanization for the eradication of weeds. Hand-weeding is necessary under such conditions. Weed control constitutes one of the principal costs of onion production. In the United States, Lachman (42) found that cultivating and weeding make up nearly 40% of the total labour cost in growing onions. Weeding probably makes up 30 to 40% of the total labour cost in growing onions in Ceylon.

Since the wages of labour are increasing every year, the profits obtained from onion farming are decreasing. This has necessitated the use of herbicides to control weeds. During the past several years, research to find selective herbicides for onions and thus reduce weeding labour costs has been extensive in the United States but not in Ceylon. Herbicides have generally given a degree of control, but not total eradication of weeds. The degree of control has varied with differences in soil type, moisture level of the soil, the system of irrigation adopted and the temperature. Most of the research work done has been on the onion *Allium cepa* L. and practically none has been conducted on the short season variety of onion, *Allium ascalonicum* L., commonly known as shallots.

Shallot, *Allium ascalonicum* L. is a member of the Liliaceae family. It is a smaller plant than the normal onion *Allium cepa* and produces clusters of bulbs at the bases of the leaves--the parent bulb divides into a number of cloves, which remain attached at the bottom (19, 57, 58, 66). The shallot is an annual and may be considered as a cultivated variety or deviate from the *Allium cepa* L. It is a native of Palestine and derives its specific name from Ascalon, where it grows in great abundance (36). Since the duration of the shallot crop in the field is about sixty to seventy days, depending on the season, the time and number of applications of herbicides play an important role in the control of weeds without damage to the crop.

One of the primary goals of a weed control programme, be it mechanical or chemical, is to obtain the greatest possible reduction in weed stand without injuring the crop (20). Hand weeding is a costly operation which is often impracticable, and it is in providing an alternative to hand-weeding that herbicides can be most valuable (58). Chemical weed control can be stated to be an applied field of plant physiology, and the action of herbicides involves the physiological processes in both weeds and plants (20).

Since no studies had been conducted in Ceylon to determine hand-weeding costs of onions and savings, if any, which might be effected by the use of herbicides, field experiments were conducted at the Agricultural Experiment Station, Jaffna, Ceylon, to determine:

(a) The comparative cost of production between the use of herbicides and hand-weeding;

(b) The exact time of the application of the herbicide to obtain maximum weed control and least possible damage to the shallots;

(c) The best dosage of the most effective herbicide;

(d) The influence of the systems of irrigation on the weed population and control;

(e) The influence of weed control on the number of bulbs formed and yield.

REVIEW OF LITERATURE

The earliest agronomic methods of weed control was effected indirectly in the form of crop rotation. In 1832 De Candolle (11) developed the theory of crop rotation. He based his theory on the idea that succeeding crops should be those that would not be affected by whatever toxic substances that were left behind by the preceding crop. Knott (41) defines crop rotation as the systematic succession of certain crops, year after year on the same land. Systematic crop rotation is not so common in vegetable growing as in general farming. In the Western United States vegetables or other cash crops occupy the land for several years between periods of alfalfa (*Medicago sativa* L.). Noxious weeds have great difficulty in maintaining their existence on land subjected to systematic rotation of crops (41).

Clements (17) indicated that plant competition is a physiological process which occurs only when two or more kinds of plants demand their nutritional and other requirements from a place where the supply is inadequate. Shadbolt & Holm (63) reported that when plants are grown in competition with one another, several factors of the environment tend to be altered and this will adversely affect the growth of the plants. The most important factors are: soil moisture, soil nutrients, and light intensity. Weeds have been found to interfere with the uptake of nutrients from the soil, particularly nitrates, which should be solely for the crop. Weeds also tend to interfere with the light and carbon dioxide supplies of the crop plants (63). Mann and Barnes (43) indicated that certain weeds when grown in competition with barley, were able to take up nitrogen at the expense of the crop. Blasser and Brady (11) reported that many weeds were better able to absorb potash from the soil than forage grasses and legumes.

Competition in Vegetable Crops:

Weed control is essential for the growing of onions as they are poor competitors of weeds. Most weed seeds germinate quickly and soon outgrow the young onion plants. Onions are slow to get started even after the seedlings appeared above ground. Shadbolt and Holm (64) found that there was a decrease in the yield of vegetables as the period of competition and percentage of weed stand increased. The yield of carrots was reduced by 78% when there was a 15% stand of weeds for a period of 5-1/2 weeks and the yield was reduced by 91% if the weed population was 50% for a period of 5-1/2 weeks. When onions were subjected to intense weed competition, small bulbs were formed early and failed to reach normal size. Bulb formation occurred early competing with weeds for six weeks, while plants which were free from weed competition for the same period of time showed normal growth. The reduction in weight of onions was severe when the weeds were in competition for six weeks. They (64) also observed that while under the influence of competition, the number of leaves per plant did not increase but remained nearly constant. This they attributed to the bulb development which occurred during competition. This was in agreement with the observations made by Heath (35), who reported that leaf production ceases when bulb formation begins. The loss of ability to produce new leaves appears to be a natural consequence of bulb initiation. Thus if only a small number of leaves emerge when bulbing is initiated, small bulbs can be expected to result.

Pavlychenko and Harrington (55) studied the root development of weeds and crops and reported that one of the first indications of injury from competition appeared in the root system. This is consistent with the observations made by Shadbolt and Holm (64) who found injury to underground portions to be much greater and also to occur sooner than injury to the tops of plants.

Herbicides Used to Control Weeds in Onions:

Several herbicides have been found to be effective in the control of weeds in onions on various types of soils. Among these are 3-(p-chlorophenyl)-1, 1-dimenthyl urea (monuron), isopropyl N-(3-chlorophenyl) carbamate (CIPC), a-chloro-N, N-diallylacetamide (CDAA), a-chloro-N, N-diallylacetamide + trichloro benzylchloride (CDAA + TCBC) and a-chloroallyl diethyl dithiocarbamate (CDEC). Monuron has been tested widely both as a pre-emergence and as a post-emergence herbicide (31, 32, 49, 50). CIPC has also been in commercial use for quite some time. Combinations of monuron and CIPC had given effective weed control on many occasions (31, 32). More recently, CDAA, CDAA + TCBC and CDEC have been in use by investigators, and of the three, CDAA has shown considerable promise for use in onions (16, 56). Warren (72) conducted experiments indicating CIPC to be a valuable herbicide for weed control in onions grown on muck soils. His results indicated that a combination of CIPC with certain other weed-killers was effective as a pre-emergence application in controlling weeds in onions. This was in agreement with the work done by Grigsby and Ries (31). They reported that CIPC at 4 lb/A with 0.5 lb 2,4-D or monuron controlled weeds as well as twice as much of either compound alone. Alban (1) was also of the opinion that such combinations of herbicides tend to give better weed control than the compounds alone.

Dallyn _et al_. (24) reported that several years of results have indicated that the best herbicide for transplanted Sweet Spanish onions grown in New York is CIPC. They recommend that the first application be made between the time of setting and the appearance of the first weeds, which is normally two to four weeks. Depending on the weed problem, subsequent applications can be made at three to four week intervals. The application preferably should be in band sprays directed towards the base of the plants; the rate being 3 to 4 lb/A. Noll (47) observed that the pre-emergence treatments of CIPC at 6 and 8 lb/A gave significant increase in weed control. In 1959 (48) he investigated the use of chemicals for weed control in onions grown in mineral soils and reported that CDAA in a pre-emergence treatment at the rate of 8 lb/A gave better weed control than CIPC. A post emergence treatment of the same herbicide had little effect on weed control.

Chemicals (23)

a. diuron .. N-(3,4-dichlorophenyl)-N, N-dimethylurea

b. CDAA .. a-chloro-N, N-diallylacetamide

c. CDAA + TCBS .. a-chloro-N, N-diallylacetamide + trichlorobenzylchloride

d. CDEC .. 2-chloroallyl diethyldithiocarbamate

Effects of Environment on the Action of Herbicides:

a. Soil Moisture: Havis et al. (33) studied the influence of soil moisture on the activity of EPTC, CDEC, and CIPC applied at the rate of 8 lb/A. Their results indicated that EPTC was an effective pre-emergence herbicide when applied to a dry soil, and its performance could be enhanced by irrigation after the application of the chemical. On the other hand failure was observed when application was made to wet soil. CDEC was affected by soil moisture in the same way as EPTC but the degree of control was not as great in the presence of moisture at the time of application.

Antogini summarized the work done by others on the activity of EPTC as affected by soil moisture at the time of application and reported that poor weed control was associated with wet soil at the time of application of the chemical(5).

Althaus and Gleason (4) studied the recent developments in the use of CDEC as a herbicide for vegetables and reported that the tolerance of crops was very closely related to depth of seeding. Sweet and Cialone (68) studied the factors influencing the performance of CDEC and reported that mechanical incorporation was inferior to irrigation as a means of enhancing CDEC activity when the soil was fairly dry. They also obtained superior results with a higher dosage of water immediately after applying CDEC but were reluctant, however, to make any definite statements as to the reasons for such a result. They felt that one possibility was that mechanical incorporation resulted in somewhat deeper penetration of the herbicide than did irrigation, and this might have caused either some additional microbial action or soil fixation. They concluded that microbial activity probably had little to do with CDEC failures, but undoubtedly was a major method by which the herbicide was removed from the soil. Timing of the application was very important in that delayed applications at the time of crop seed sprouting caused severe stand reductions and stunting of surviving plants.

Splittestoesser et al. (67) studied the effects of the environment upon herbicides applied pre-emergence and found that water moved CDAA, atrazine, and simazine into the soil. In South Dakota, a pre-emergence application of 4 to 6 lb/A of CDAA on warm soil controlled foxtail (Setaria sp.) effectively if normal amounts of rain fell within seven to ten days after the application. In wet soil the effectiveness of the spray was reduced if less than one half inch of rain fell in the first week after application. Sheets et al. (65) observed that the inactivation and loss of herbicides which are active in soil for three weeks or less are attributed mainly to three processes--vaporization, chemical reactions, and soil adsorption. Microbial action and leaching may account for loss of a major part of only a few such herbicides. They were of the opinion that carbamates may be lost from the soil as vapours yet some of the material persists for several weeks, CIPC persisting longer than IPC. The retention of CDAA by the soil was found to increase as the percent of organic matter in the soil increased, and losses increased as soil moisture increased. At low soil moisture levels the retention was greater at 38°C than at 21°C.

b. Temperature and Soil Type: The work of Havis et al. (38) is consistent with the observations made by Ogle and Warren. Ogle and Warren (54) reported that the herbicidal breakdown was found to be proportional to the temperature as would be expected in microbial decomposition. In addition to the temperature, they also stated that soil type had an important effect on the breakdown of herbicides, the rate increasing progressively from sandy soil to silt loam to muck. The amount of organic matter present in the soil was believed to be partly responsible for this effect of soil type. Soil types also played an important role in the herbicidal movement and retention. CIPC was found to be highly resistant to movement in sandy soil, silt loam, and muck. Ogle and Warren (54) demonstrated that the activity of monuron was greater in mineral soils than in organic soils.

Crafts and Drever (22) reported that the inactivation of some of the herbicides is greater in heavier soils or soils high in organic matter than in lighter soils or soils low in organic matter. They were of the opinion that the factors contributing to this effect may be greater microbial population or conditions favouring their proliferation and activity, such as high temperature, adequate moisture, and organic matter in the soil. Gantz and Slife (30) stated that in humid agricultural regions, leaching was one of the major factors influencing the success of pre-emergence herbicides. The chances of losing pre-emergence herbicides through leaching appeared to be greater in soil low in clay and/or organic matter content. Fixation of herbicides helped to reduce the leaching losses in soils having high exchange capacities. The two most important factors affecting herbicidal breakdown under pre-emergence conditions appeared to be temperature and moisture. Even though persistence actually may be dependent upon microbial activity or chemical decomposition, these in turn are affected by temperature and moisture (71).

c. Microorganisms: There are great differences in the time taken for the breakdown by microorganisms--long time for the substituted ureas and a short period for 2,4-D. On the other hand, 2,4,5-T takes about three times as long as 2,4-D and TCA takes about seven times as long as monochloacetic acid. This indicates that there is considerable variation between closely related compounds. There is a strong correlation between conditions favourable for bacterial growth and the speed of disappearance of toxic residues of herbicides; high moisture, temperature, and organic matter favour rapid disappearance. In many instances, there is a lag phase during which there is little or no disappearance, followed by a period of rapid breakdown. This phenomenon is thought to be due to the time required for the soil to develop a microflora capable of detoxicating the specific herbicide. Once a soil has built up the microorganisms necessary to break down a herbicide, subsequent application of that same herbicide may be detoxified without a further lag phase. A situation may arise when the same soil-acting herbicide applied to the same area at frequent intervals may not give weed control for the expected period because of more rapid breakdown (36).

d. Effect of the Method of Irrigation on the Action of Pre-emergence Herbicides:

Ashton (6) reported on the influence of irrigation on pre-emergence herbicides. Pre-emergence herbicides were found not to perform as uniformly under furrow irrigation as under rainfall or sprinkler irrigation. It was also shown that CDEC, EPTC, and CIPC were more effective when sprinkler irrigated than when furrow irrigated. Diuron was not affected as much by the method of irrigation. Antogini (5) reported that incorporation of herbicides into the soil by irrigation had improved weed control while Ashton et al. (7) reported that if chemicals were too dilute in the area where the weed seeds were present, the weed control would be reduced. Menges (44, 55) reported on the effect of irrigation methods on the performance of pre-emergence herbicide treatments. Incorporation with water increased the activity of CIPC, CDEC, and EPTC.

Jordan et al. (39) indicated that mechanical incorporation with furrow irrigation increased the effectivenes of several herbicides. Incorporation of the chemical by sprinkler irrigation, while effective, was not practical over a large acreage soon after spraying. Incorporation with water was found to increase the activity of CIPC, and EPTC.

Danielson et al. (25, 26) found soil incorporated carbamates to differ widely in selectivity and persistence. This depended on the chemical structure, formulation, method of irrigation, temperature, and soil composition. Sweet and Cialone (68) reported that in determining the effects of CDEC volatility, a dry or moist soil surface was unimportant. Time of application was however extremely important. Delayed application made at the time of seed germination caused severe reductions and stunting of the plants that survived. The effectiveness of CDEC was increased either by mechanical incorporation or water applied after the application of the chemical. To obtain maximum effect of CDEC the active chemical must be in the zone of seed germination when the radicles are emerging. This will give excellent weed control regardless of other environmental factors.

e. Other Factors: Holly (37) studied the problems that arose in the use of pre-emergence herbicides and reported that many of these newer herbicides do not enter the foliage of weeds in effective amounts but are taken up from the soil by germinating seedlings. He also reported that when a soil is dry and the chemical is sprayed on the surface, the chemical remains at or very near the surface. It may then be decomposed by either photochemical decomposition, particularly in ultra-violet light, or by volatilization into the atmosphere. On entry into the soil, the herbicide is subjected to many physical, chemical, and biological processes. One is adsorption, which results in the herbicide being bound on the surfaces of organic matter and clay colloids. The degree of adsorption varies according to the herbicide and soil type. Adsorption renders the herbicide biologically unavailable. Rain-fall may cause leaching of the herbicides, the degree of leaching varying with the chemical, and on the water solubility of the herbicide. However, in the absence of soil incorporation, leaching can be an advantage in that it can carry the herbicide to the germinating weed seed which may be near the surface or at a wide range of depths. Uptake and breakdown by resistant plants, chemical breakdown in soil hydrolysis, and microbial action also can cause the disappearance of herbicides from the soil (37).

Mode of Action of Herbicides Used:

The herbicides used on onions are not of the auxin type. None of them appear to be related to the naturally occurring hormones or growth factors. The selective action of these compounds on different species vary widely. They differ from those of the auxin herbicides (1).

a. The Substituted Carbamates: The toxic action of this class of compounds has been known since 1929. However, their selective herbicidal properties were only observed by Templeman and Sexton (69). The carbamates act only on germinating seeds and seedlings. They are absorbed only by roots and not by leaves, except when the concentration is very high. This permits their use in pre-emergence applications to seed beds. The phsiological action of the carbamates consists essentially of a disturbance in the growth process. Doxey (27) reports that certain aspects of cell division in roots are completely dislocated. The compounds are mitotic poisons.

Scott and Struckmeyer (61) studied the morphology and root anatomy of squash and cucumber seedlings treated with CIPC and reported that the most important effects of this chemical are the apparent inhibition of mitosis, the enlargement of the cells and the maturation of tissues near the root apex. Squash seedlings exhibited little response at concentrations of 1,5 and 10 ppm; at 15 ppm secondary roots were inhibited. The response was more pronounced in cucumber seedlings. Primary roots, secondary roots, and the shoots were inhibited at these four concentrations, the response increasing with the dosage and time. The squash seedlings treated with 15 ppm CIPC showed radial elongation of endodermal and pericycle cells in the mature region of the root. In cucumber roots, the region of elongation and the region of maturation were affected. There was severe distortion of the root tissue at higher concentrations. The endodermal and pericyclic cells in roots of treated seedlings were radially elongated. This accounted for the swollen appearance of the roots. Some of the enlarged cells had abnormal nucleoli in their nuclei.

In barley roots, Canvin and Friesen (15) observed that CIPC at 1 ppm completely inhibited cell division. The root and cell structure appeared to be normal but no cell division was to be found. The arrangement of cells was disturbed in treated roots. Endopolyploidy was found to be common and large cells containing several times the normal complement of chromosomes were seen. The chromosomes were scattered and appeared to be in the prolonged pseudo-metaphase stage. Due to the failure of cell wall formation, multinucleate cells resulted.

Canvin and Friesen (15) studied the effects of CIPC on germinating barley and pea. CIPC at 1 ppm completely inhibited cell division in barley and at 10 ppm to 100 ppm caused endopolyploidy, binucleate cells, and other abnormalities. On the other hand, pea roots were only slightly affected in that fewer dividing cells were noted in treated roots as compared to untreated roots.

Ennis (28) studied the effects of O-Isopropyl-N-phenyl carmamate on thirteen monocotyledonous species of plants treated at the germination stage and found that all showed similar responses to the compound. There were lack of root and shoot elongations with the swelling of these parts. The roots were bulbous and stubby with the coleoptile region swollen. Young established cereals treated with this carbamate ceased to grow acropetally and leaves became dark green. No epinasty occurred.

Ennis also treated thirty-nine dicotyledonous species of plants with this compound at the germination stage and found that of the thirty-nine, fifteen showed responses to the chemical. Plants from six of these species recovered from the treatment while the others were permanently inhibited. The reactions in the nine species were similar to those observed in the monocotyledonous species in that the hypocotyl failed to elongate and the root system was stunted. Most of the species responding to the carbamate developed to the two-leaf stage but the cotyledons did not fully expand and the stem apex failed to grow. There were marked abnormal cytological changes in the roots of oat and barley treated with O-Isopropyl N-phenylcarbamate in that the mitotic cycle was interrupted, metaphase blocked, occurrence of giant nuclei and an increase in the chromosome number in certain cells of both roots and shoots. Cell division was found to have ceased in the apical meristems of the roots and shoots. Great cell enlargement and maturation was also observed in these cells and those in the process of expansion. When the carbamate was applied to the tops of oats plants in the boot stage, cessation of the panicle growth was observed. The same treatment on the seedling stage of oats did not show any response.

b. <u>The Substituted Ureas</u>: The substituted ureas were discovered purely by chance during the screening of potential drugs for the cure of an intestinal disease in chickens (8). They have proved to be among the mostpowerful phytotoxic compounds. They are non-volatile and non-corrosive and non-toxic to mammals. They are such powerful herbicides because of their high phytotoxicity and their exceptional persistence in the soil. There is a high degree of adsorption onto soil colloids and thus a decrease in the attack by soil microorganisms. Among them the clorinated compounds are most resistant and at high rates of application, their persistence may be reckoned in years (8).

The mode of action of these herbicides is very different from that of the auxin weedkillers. They appear to be absorbed by both the leaves and the roots. The first symptoms to appear are necrotic areas in the leaf margins, but translocation and subsequent killing of the treated plants appear to be rapid when the chemical is taken in the roots. It has also been shown that the protein metabolism of the treated plants is seriously disturbed (23).

Muzik et al. (46) studied the absorption, translocation, and action of monuron with velvet bean (Stizolobium deeringianum Bort.). They reported that the action of monuron was different from that of 2,4-D which caused extensive cell proliferation and tissue modification in velvet beans. 2,4-D affected the young meristematic portions of the plant first, causing epinasty, twisting, and malformation of young leaves. It also induced division in parenchymateous cells of the plant. Monuron, on the other hand, did not cause epinasty. It affected older leaves first. Parenchyma cells lost tugor and collapsed, causing the plants to wilt. The parenchyma cells were not induced to divide as in the action of 2,4-D. Their studies also indicated that monuron entered either through aerial shoots or through roots; but was not translocated from the leaf to the stem. The entry through leaves was found to be slower through surfaces with a thick cuticle. Movement within the plant was primarily towards the apex and the path of travel was through the xylem and the transpiration stream.

Freed (29) proposed that the chlorotic appearance of seedlings emerging from monuron treated soil was due to the interference of this compound with nitrogen metabolism. Work done by Christoph and Fisk (18) indicated that the killing action of the urea type herbicides was by loss of tugor, chlorosis, and progressive dieback of leaves. At sublethal dosages it caused loss of apical dominance with resultant increase in tillering. Mitosis in meristems was retarded and inflorescences were deformed. Both root and shoot growth were reduced. Soybean and tomato plants became chlorotic from monuron treatment. The young leaves collapsed, palisade tissue was disorganized and vascular differentiation was reduced. In onion, the root tips lacked normal differentiation of the meristem. Nuclear breakdown, disruption of the epidermis, and lowered mitotic activity was also observed. The symptoms indicate that the mode of action goes beyond a cessation of photosynthesis and an attendant starvation.

c. The Cloroacetamides: This class of herbicides, the alpha-chloroacetamides, was introduced in 1954 (8). These compounds are toxic to germinating seeds of many weeds, particularly grasses. These compounds have proved to be less affected by variations in soil moisture and organic matter than some other pre-emergence herbicides (23).

Acetamides are absorbed through the roots. They show little or no contact foliar activity. However, established plants of susceptible species can be severely damaged or killed by post-emergence application at higher levels (3). CDAA acts directly on young seedlings. It has been found to inhibit cell division in barley roots but not in pea roots (23). At 10 ppm germinating barley seeds showed few dividing cells in the roots while at 100 ppm. the cell division was practically stopped. Scientists at Monsanto Chemical Co. suggest that CDAA may interfere with a sulphydryl enzyme system (23, 38). Experiments conducted by Jaworski (38) on germinated seeds of wheat indicated that the oxygen uptake was reduced 22.5% by CDAA at 10 ppm.

The alpha-cloroacetamides reported to be highly effective even on soils relatively low in moisture. The effectiveness of these compounds under such conditions is probably related to their retention in the soil in an available form. Laboratory tests have shown that these compounds are fixed in the uppermost layer of soils, and are thus effective against seedlings germinating in this layer (9, 10).

Weeding Costs in Onions:

There appears to have been few studies conducted to determine the costs of hand-weeding onions and the possible savings which might be effected by the use of herbicides. Alban (2) reported that in a commercial field of onions the application of CIPC at 6 lb/A as a pre-emergence spray followed by three post-emergence sprays at the rate of 4 lb/A of the same herbicide reduced the hand-weeding costs from $75 per acre to $45 per acre. In his experiment with smaller sized plots at the Ohio Agricultural Experiment Station, he observed that a pre-emergence application of CIPC at 6 lb/A followed by a single post-emergence application also at 6 lb/A reduced hand weeding costs from $129 to $75 per acre. Nylund (51) studied the effects of various combinations of CMU and CIPC on hand-weeding costs and reported in 1955 that the application of either 1.6 lb monuron/acre or 8 lb CIPC/acre used as a pre-emergence spray when the onions were at the one-leaf stage, reduced hand-weeding labour costs by 44%.

Nylund et al. (52) studied the comparative costs of weeding onions by hand or with monuron, CIPC and CDAA during the years 1956 and 1957. In the year 1956, the labour required to hand weed onion was 170 hours per acre which cost $127 and in the year 1957 the labour to hand-weed was 111 hours and the cost $83 per acre. Monuron applied three times at 1.6 lb/A in 1956 reduced weeding time by 70% and the weeding costs by 50%. Three applications of a mixture of 0.8 lb. monuron and 4 lb CIPC reduced the weeding time by 54% and the weeding costs by 26%. In their experiments in 1957, a single pre-emergence application and a double application of 1.6 lb/A of monuron, 8 lb/A CIPC, or 4 lb/A of CDAA as a post emergence treatment reduced total weeding time by about 50%. A single application of herbicides reduced weeding costs 34% to 40%; the second application did not reduce the weeding costs further.

MATERIALS AND METHODS

General:

Field experiments were conducted from September, 1962, to January, 1964, at the Agricultural Experiment Station, Jaffna, Ceylon. The soil in this area was the Red Loam, typical of the Red Soil Region in Jaffna.

Fertility:

The entire experimental area was planted with a leguminous crop, Sunhemp (*Crotolaria juncea* L.) and the plants removed for green manure. The land was then ploughed and organic manure applied at ten tons per acre prior to the second tillage operation. The soil was in a very good physical condition at the time of planting. A fertilizer mixture containing the following:

N : 22 lb/A, P_2O_5 : 45 lb/A and K_2O : 14 lb/A

was applied broadcast. The N was applied in the form of sulphate of ammonia, the P_2O_5 in the form of double superphosphate and the K_2O in the form of sulphate of potash. A further broadcast application of 22 lb N/A in the form of sulphate of ammonia was given three weeks after planting. This application was immediately after the first hand-weeding. The pH of the soil was taken before and after the experiment. The pH ranged from 6.8 to 7.0 and was not changed by the experimental procedures.

Seed Material and Planting:

Medium sized bulbs of the commercial variety Jaffna Red was used for planting. The diameter of the bulbs varied from 1/4 inch to 1/2 inch.

Experiments:

A set of two experiments was planted each time; one received sprinkler irrigation while the other received flood irrigation. The sprinkler worked for about four hours once every two days; the flood irrigated plots received irrigation once every three days--this being the normal interval of irrigation practiced by farmers in Jaffna.

Experiment 1: This experiment was planted on September 4, 1962. The seeding rate was 1568 lb/A. The herbicides were sprayed on September 12, 1962, with a knapsack sprayer. The plots were 12 ft. x 5 ft. each, and each in turn split into three sub-plots of 4 ft. x 5 ft.

Treatments:

diuron .. 1, 2 and 3 lb/A

CDAA .. 6, 8 and 10 lb/A

CDAA + TCBC .. 6, 8 and 10 lb/A

CDEC .. 6, 8 and 10 lb/A

A control plot which received hand-weeding accompanied these treatments. Four replications of each treatment were made. The crop was harvested on November 12, 1962. At the time of harvest the total weight, including leaves, and the cured weight of bulbs were recorded separately.

Weed Population: Weed population counts were taken using a one foot square quadrat. The quadrat was placed at three different places within the sub-plot and the number of weeds within each area was counted. The weed count was taken on September 24, 1962--twelve days after spraying the herbicide.

After the weed counts were made, the plots were weeded manually. In order to obtain data on hand-weeding labour cost, all hand-weedings were timed with a stop watch. The hand-weeding labour costs were calculated at Rs.0.50 per hour, and the spraying costs were calculated by adding the cost of the chemical used for an acre to the cost of spraying (Rs. 4.75 equals U. S. $1.00).

Since the sprinkler irrigation was being used for the first time at this experiment station, there was difficulty in getting the sprinklers to work uniformly. The force of water from the overhead water tank at the station was not sufficient to rotate the sprinklers and a water pump had to be used. Two of the sprinklers failed to function by the end of the fourth week after planting and this resulted in giving flood irrigation for the rest of the period until harvest.

Experiment 2: This experiment was planted on November 2, 1962, and sprayed on November 14, 1962--twelve days after planting. The spraying was delayed due to the nonavailability of some of the herbicides at that time. The crop took 65 days to mature, five days longer than the previous crop.

The herbicide treatments applied in this experiment included those in Experiment 1 and in addition the combinations of the following:

CDAA + diuron at 3 + 1 lb/A respectively

" + " at 6 + 1/2 lb/A "

CDEC + " at 3 + 1 lb/A "

" + " at 6 + 1/2 lb/A.

The size of the plots were 5 x 5 ft. and the treatments were randomized. The seed rate was increased to 1792 lb/A. The seed rate was increased to study the effects of the herbicides on weeds in a closer spaced crop of shallots and also the effect of closer spacing on the yield.

Experiment 3: This experiment was planted on January 24, 1963, sprayed on January 28, 1963, and harvested on March 26, 1963. The herbicide treatments applied in this experiment were the same as in Experiment 2 except that diuron at 2 and 3 lb/A, CDAA + diuron and CDEC +diuron at 3 + 1 lb/A respectively were eliminated. Hand weeding was done after spraying.

Experiment 4: This experiment was planted on January 28, 1963, sprayed on February 1, 1963, and harvested on April 1, 1963. This was an exact duplicate of Experiment 3 but the plots were only sprayed. No hand-weeding was given after spraying except for the treatment receiving hand-weeding.

Experiments 2, 3, and 4 were planted in a plot of land that had been fallow for a period of over ten years. The weed population was high, the predominant weeds being Tribulus terrestris Link, Boerhaavia diffusa Link, and Echinocloa colunum Link. This plot was not planted with a leguminous crop prior to applying the treatment. All other cultural operations and organic manure and fertilizer applications were the same as in Experiment 1. The pH ranged from 7.0 to 7.1. Observations were taken as in Experiment 1. The sprinklers worked quite well. No two experiments were conducted in the same place.

Experiment 5: This experiment was planted on June 10, 1963, sprayed on the 15th of June and harvested on August 11, 1963. The crop was good and there was no insect or disease attack both under either sprinkler irrigation or the flood irrigation. There were five replications of each treatment and the plot size was 5 x 5 ft. The treatments were randomized. This experiment was conducted to study the yields of the three promising herbicides namely CDAA, CDAA + TCBC and CDEC at 10 lb/A under the two systems of irrigation. Since sufficient data on weeding costs had already been obtained, this was not included.

Rate of Growth of Onion in Sprayed Plots and Hand-Weeded Plots:

Five plants in each plot were labelled and their daily growth was recorded from the seventh day until the fortieth day. Thenceforth the height decreased as the base of the plant increased in girth due to bulb development.

Organic Manure and Weed Population;

Since there was an increase in the weed population in the plots which received organic manure, an experiment was carried out to study the percent increase in weeds with the increase in organic manure application. Four plots of 15 x 10 ft. in dimension were laid out and the organic manure treatments at the rates of 5, 10, 15 and 20 tons per acre applied. A check with no organic manure accompanied them. Normal cultivation practices were adopted.

Time of Application of Herbicide:

A set of twenty 5 x 5 ft. plots previously steam sterilized was planted with shallots. One-eighth ounce of seeds of *Boerhaavia diffusa*, *Amaranthus viridis*, and *Echinocloa colonum* was sown in each plot at the time of planting of the onion. Ten were sprayed with CDAA while the other received CDEC, both at 8 lb/A at one day interval; i.e. Plot 1 received the spray on the day of planting while Plot 10 received the spray on the tenth day after planting. This was done to determine the correct stage of the crop at which the herbicide should be sprayed in order to achieve maximum control of weeds with a minimum damage to the crop.

The herbicides used were donated by the United States Operation Mission in Ceylon through their adviser Dr. Buford H. Grigsby.

Pest Control: The entire area planted was sprayed with "Folidol" (O, O-diethyl O-p-nitrophenyl thiophosphate) at the rate of 1 oz. (fluid) in 6 gallons of water at weekly intervals to prevent damage from thrips. Thrip attack was higher during Maha Season* than during Yala Season.** Weeds killed by herbicides attracted fungi during the wet season. The common fungus was *Perenospora* sp. This necessitated fungicidal

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*Maha Season: The north-east monsoon period, late October to February when heavy rainfall is limited to the northern and eastern parts of the island.

**Yala Season: The south-west monsoon period, late April to September when the rain is confined to the south-west quarter of the island.

treatments. "Perenox" (Cuprous oxide) at the rate of 1 oz. in two gallons of water was sprayed whenever fungus attack was suspected. Fungi population were lower in plots receiving sprinkler irrigation than under flood irrigation. They were almost absent in plots that received hand-weeding.

Saline Land Trials:

Since a good portion of the land around the Vadamaradchy Lagoon in Jaffna was also planted with shallots, one experiment was conducted at the Vadamaradchy Lagoon Scheme Experiment Station, Atchuvely, Ceylon. The soil in this station was of the White Clay Loam type. The pH of the soil was 8.5 and the salinity 0.03%. The tract of land had only grass and no broad leaved weeds. The grasses found were Digitaria marginata Echinocloa colonum Link, and Cyperus rotundus Link. This experiment was planted on December 15, 1962, sprayed on December 20, 1962, and harvested on February 18, 1963. No hand-weeding was done. The plots were hand watered.

RESULTS AND DISCUSSION

In shallots, it is generally necessary to hand-weed twice. The first weeding is about two weeks after planting and the second two weeks after the first weeding. During the first hand-weeding, the soil gets stirred and this brings the weed seeds from the lower levels to the surface. These seeds germinate and later compete with the crop. The pre-emergence application of herbicides eliminated the first hand-weeding. Whether or not a second hand-weeding was required depended on the effectiveness of the herbicides.

Table 1 shows the treatments applied in Experiment 1 with weeding time, weeding costs, and yields per acre under sprinkler irrigation while Table 2 shows the same under flood irrigation. With the exception of diuron which gave almost total weed control and severe damage to the crop, all other herbicides gave satisfactory weed control under both sprinkler as well as flood irrigation. CDAA + TCBC gave the best results with the lowest weeding cost; at 10 lb/A a decrease of 35% with an increase in yield of 86% over the hand-weeded control. The highest yield obtained was at 6 lb/A application

TABLE 1.--Weeding costs and onion yields under various methods of weed control.

Experiment 1. Sprinkler Irrigation

Weed control treatments Chemical/A	Labour to hand-weed (hours)	Weeding Costs/A--(Rupees)			Onion Yields
		Hand-weed labour cost	Approx. Herb. cost	Total	Cwt/A
Hand-weeded	1172	586	-	586	60
Diuron 1	47	23	32	55	36
Diuron 2	00	00	48	48	10
Diuron 3	00	00	64	64	9
CDAA 6	629	314	83	397	91
CDAA 8	623	316	105	421	85
CDAA 10	536	268	127	495	87
CDAA +					
TCBC 6	587	293	115	408	124
TCBC 8	484	242	149	391	96
TCBC 10	395	197	183	380	113
CDEC 6	644	322	105	427	99
CDEC 8	541	270	135	405	89
CDEC 10	467	233	165	395	93
L.S.D. at 5%					24.11
L.S.D. at 1%					32.09

TABLE 2.--Weeding costs and onion yields under various methods of weed control.

Experiment 1. Flood Irrigation

Weed control treatments Chemicals/A	Labour to hand-weed (hours)	Weeding costs/A--(Rupees)			Onion Yields
		Hand-weed labour cost	Approx. herb. cost	Total	Cwt/A
Hand-weeded	1364	682	-	682	70
Diuron 1	00	000	31	31	26
Diuron 2	00	000	48	48	8
Diuron 3	00	000	64	64	4
CDAA 6	247	124	82	206	132
CDAA 8	217	109	105	214	123
CDAA 10	215	102	128	230	134
CDAA +					
TCBC 6	322	161	116	277	92
" 8	322	161	149	310	90
" 10	214	107	183	290	89
CDEC 6	468	234	105	339	136
CDEC 8	247	124	135	259	138
CDEC 10	287	144	165	309	142
L.S.D. at 5%					39.84
L.S.D. at 1%					53.26

of CDAA + TCBC, an increase of 104% was obtained with the weeding cost reduced by 30%. Under flood irrigation, CDEC at 10 lb/A gave the highest yield--102% more than the control with the weeding cost reduced by 54%.

Table 3 shows the effects of combinations of herbicides on weeding costs and yields per acre under sprinkler irrigation while Table 4 shows the same under flood irrigation. Diuron and combinations of diuron with CDAA and CDEC showed promise. However, these did not give an increase in yield over the hand-weeded control. The weeding costs, however, were reduced.

CDEC at 8 lb/A gave the highest yield under sprinkler irrigation, 11% more than the hand-weeded control with the weeding cost reduced by 44%. This yield was also 141% more than the yield obtained from the unweeded plot. The lowest weeding cost was obtained from CDAA at 10 lb/A; the weeding cost reduced by 46% with a 6% increase in yield over the control. With flood irrigation, CDAA at 8 lb/A gave a 17% decrease in weed control with no increase in yield. This yield is 93% more than the yield obtained from the unweeded plot. CDAA + TCBC at 8 lb/A gave the best result in terms of weeding cost with a decrease in yield over the hand-weeded control. Diuron at 1 lb/A showed promise with the

TABLE 3.--Effects of combinations of herbicides on weeding costs and yields.

Experiment 2. Sprinkler Irrigation

Weed control treatments Chemicals/A	Labour to hand-weed (hours)	Weeding costs/A--(Rupees)			Onion yields
		Hand-weed labour cost	Approx. herb. cost	Total	Cwt/A
Unweeded	-	-	-	-	71
Hand-weeded	1134	567	-	567	154
Diuron 1	272	136	32	168	150
Diuron 2	225	113	48	161	123
Diuron 3	196	98	64	162	62
CDAA 6	853	427	83	510	150
CDAA 8	465	232	105	337	158
CDAA 10	348	174	128	302	164
CDAA +					
TCBC 6	450	225	116	341	122
" 8	443	221	149	370	107
" 10	334	166	183	349	58
CDEC 6	515	258	105	363	165
CDEC 8	360	180	135	315	171
CDEC 10	276	138	165	303	137
CDAA + diuron					
3 + 1	243	122	65	187	104
6 + ½	196	98	91	189	99
CDEC + diuron					
3 + 1	348	174	77	251	122
6 + ½	229	114	113	227	116
L.S.D. at 5%					44.33
L.S.D. at 1%					59.10

TABLE 4.--Effects of combinations of herbicide on weeding costs and yields.

Experiment 2. Flood Irrigation

Weed control treatments Chemicals/A	Labour to hand-weed (hours)	Weeding costs/A--(Rupees)			Onion Yields
		Hand-weed labour cost	Approx. herb. cost	Total	Cwt/A
Unweeded	-	-	-	-	70
Hand-weeded	1222	611	-	611	136
Diuron 1	457	228	32	260	115
Diuron 2	360	180	48	228	73
Diuron 3	232	116	64	180	47
CDAA 6	947	474	83	557	132
CDAA 8	791	396	105	501	135
CDAA 10	772	361	128	489	123
CDAA +					
TCBC 6	653	327	116	443	109
" 8	505	252	149	401	129
" 10	417	209	183	392	124
CDEC 6	864	432	105	357	123
CDEC 8	762	381	135	516	129
CDEC 10	708	354	165	517	156
CDAA + diuron					
3 + 1	396	198	65	263	102
6 + ½	242	121	91	212	83
CDEC + diuron					
3 + 1	650	325	77	401	96
6 + ½	483	241	113	355	88
L.S.D. at 5%					42.46
L.S.D. at 1%					56.50

combination of CDAA + diuron at 3 + 1 lb/A respectively following close to it.

Table 5 shows the effects of the more promising herbicides and their combinations on weeding costs and yields per acre under sprinkler irrigation while Table 6 shows the same under flood irrigation. All three rates of application of CDAA + TCBC at 8 lb/A gave a 104% increase in yield with a 6% decrease in the weeding cost under sprinkler irrigation. Under flood irrigation, CDAA + TCBC gave a 108% increase in yield with a 11% decrease in the weeding cost. Diuron at 1 lb/A and combinations of diuron + CDAA and diuron + CDEC gave higher yields than the hand-weeded control with a reduction in the weeding cost.

Table 7 shows the yield of onions with herbicides alone as compared with the hand weeded control under sprinkler irrigation while Table 8 shows the same under flood irrigation. No hand-weeding was done except for the control which received this treatment. All the treatments with herbicides gave better results, both in yield and the reduction in weeding costs, than the hand-weeded control. CDAA + TCBC at 10 lb/A gave an increase of 51% in yield with a decrease of 76% in the weeding cost, under sprinkler irrigation. With flood irrigation CDAA + TCBC at 10 lb/A gave an increase of

TABLE 8.--Yield of onions with herbicides alone as compared with hand-weeded control.

Experiment 4. Flood Irrigation

Weed control treatments Chemicals/A	Labour to hand-weed (hours)	Weeding costs/A--(Rupees) Hand-weed labour cost	Approx. herb. cost	Total	Onion yields Cwt/A
Unweeded	-	-	-	-	6
Hand-weeded*	1078	535	-	535	40
Diuron 1			32	32	34
CDAA 8			105	105	45
CDAA 9			117	117	56
CDAA 10			128	128	44
CDAA +					
TCBC 6			116	116	54
" 8			149	149	62
" 10			183	183	88
CDEC 8			135	135	43
CDEC 9			150	150	54
CDEC 10			165	165	55
Diuron + CDAA 1 + 6			99	99	50
Diuron + CDEC 1 + 6			121	121	52
L.S.D. at 5%					18.20
L.S.D. at 1%					24.57

*Hand-weeded only once

51% in yield with a decrease of 76% in the weeding cost, under sprinkler irrigation. With flood irrigation CDAA + TCBC at 10 lb/A gave an increase of 112% in yield over the hand-weeded control with a decrease of 84% in the weeding cost.

The unweeded plots in Experiment 3 did not give any marketable bulbs and so they were discarded. In Experiment 4, some marketable bulbs were obtained but the yield was extremely low. The yield was also affected by the season--the yields were better in Yala Season than in Maha Season.

Table 9 shows the effects of the three promising herbicides at 10 lb/A on onion yields under sprinkler irrigation and under flood irrigation. The plots treated with herbicides gave higher yields than the hand-weeded control, under both systems of irrigation. CDAA + TCBC gave a 50% increase in yield over the control under sprinkler irrigation while both CDAA and CDAA + TCBC gave a 60% increase in yield over the control under flood irrigation. The results also show that there was an increase in yield by 21% under sprinkler irrigation with CDAA + TCBC when compared with the same treatment under flood irrigation. CDAA and CDEC gave a 19% increase in yield under sprinkler irrigation when compared with the same treatments under flood irrigation.

TABLE 9.--The effects of the three promising herbicides at 10 lb/A on onion yields.

Experiment 5

Weed control treatments chemical/A	Sprinkler Irrigation	Flood Irrigation
CDAA	109	91
CDAA + TCBC	111	91
CDEC	100	84
Hand-weeded	74	58

TABLE 10.--The effect of herbicides on the yield of onions grown in saline land.

Chemical	8 lb/A	10 lb/A
CDAA	191	171
CDAA + TCBC	192	186
CDEC	198	186
Unweeded	167	155

Fig. 1--General appearance of experimental data. Unweeded plots (control) can be clearly identified.

Table 10 shows the effect of herbicides on the yield of onions grown in saline land at Atchuvely. The control was unweeded since this was a tract of land with very few weeds. The application of organic manure introduced weeds such as <u>Gynandropsis pentaphylla</u> DC., <u>Portulaca oleracea</u> Link, and <u>Amaranthus viridis</u> Link. At the 8 lb/A level of herbicide treatment CDAA gave the best result with an 18% increase in yield. At the 10 lb/A level both CDEC and CDAA + TCBC gave a 20% increase in yield over the control. With CDEC at 8 lb/A there is an additional income of Rs.639.00 deducting the cost of the herbicide and the labour to spray the herbicide. With CDEC at 10 lb/A the additional income is Rs.616.00 and with CDAA + TCBC at 10 lb/A the additional income is Rs.561.00

<u>Bulb Formation</u>:

Bulb formation was three days earlier in CDEC and CDAA sprayed plots when compared to the hand-weeded control. It was more than seven days earlier in plots which received diuron treatment. There was not much difference in plots treated with CDAA + TCBC though the plants in these plots showed symptoms of poor growth for a week after spraying.

In these experiments bulb formation occurred between 38 to 45 days from the time of planting, or 37 to 40 days from the time of sprouting. It was also observed that shoots that did not form bulbs by the 50th day remained bulbless.

Another interesting observation was that bulb formation was low during the rainy months of November, December, and January. A crop that arrived at its 35th day during the rainy season formed few bulbs. About two percent of the plants flowered, a characteristic not found in the Yala Season (April to September) though the seed material was from the same parent stock. This appears to be due to the effect of photoperiodism. Table 11 shows the temperature, the hours of sunshine and the rainfall during this period.

Thompson and Smith in 1938 (70) have shown that relatively high temperatures as well as long photoperiod is essential for bulb formation in certain varieties of onions that are commonly grown under long-day conditions. They have also indicated that temperature is more important than day-length in seed-stalk formation. Knott (41) reported that the initiation of bulbing of onions is determined by length of day modified somewhat by temperature. Some varieties will bulb in a twelve-hour day, while others may require as much as fourteen hours of light or more. Warm temperatures tend to

TABLE 11.--Meteorological Data*

Month and year	08.30 hrs. Max. temp.	Min. temp.	17.30 Max. temp.	Min. temp.	Hours sunshine	Rain-fall inches**
Sep. '62	85.15	78.82	89.03	82.21	7.45	2.65
Oct. '62	83.16	75.63	86.11	79.12	5.90	16.33
Nov. '62	81.62	75.74	84.29	78.21	7.45	10.65
Dec. '62	80.59	75.70	83.54	78.46	6.54	4.94
Jan. '63	79.04	74.38	81.56	76.55	6.51	12.40
Feb. '63	80.00	69.92	83.45	77.88	8.33	0.00
Mar. '63	82.89	74.68	86.56	79.77	8.42	2.96
Apr. '63	86.20	77.06	90.26	82.63	8.34	1.66
May, '63	88.85	80.82	93.07	85.51	9.13	0.81
Jun. '63	86.94	81.85	91.47	84.92	8.63	0.00
Jul. '63	86.20	80.17	90.21	83.37	7.81	0.20
Aug. '63	85.92	80.45	89.56	83.56	6.54	0.45
Sep. '63	86.26	80.78	90.94	84.51	9.02	0.00
Oct. '63	83.45	77.58	87.09	81.55	6.94	12.01
Nov. '63	81.23	76.22	83.85	78.37	4.56	20.25
Dec. '63	79.71	75.48	82.51	77.86	5.70	16.88

*Obtained from the Meteorological Department, Vasavalan, Jaffna.
**Obtained from the Agricultural Experiment Station, Tinnevely, Jaffna.

hasten the response to daylength, and thus are necessary for proper maturation of the bulbs. Cool temperatures tend to delay bulb initiation even if the daylength is adequate.

Heath in 1943 (34) pointed out that there is interaction between day-length and temperature with respect to flowering. He stated that long-days and high temperatures favour bulbing but discourage flowering. In a later report in 1945 (41) he stated that at temperatures high enough to encourage rapid bulbing in plants from sets, long days suppress inflorescence emergence; at temperatures low enough to prevent delay bulb formation, long days accelerate the emergence of inflorescences by increasing the rate of scape elongation.

<u>Effects of Herbicides on the Growth of Onions</u>:

a. Diuron: The crop was badly damaged by all the three levels of application, the effect being greatest at 3 lb/A. Plants become clorotic on the third day and the leaf tips were scorched. On the fifth day the entire plant was scorched. Epinasty was observed in some plants that were not badly damaged. The stand was very poor, the number of plants decreasing as the rate of application of the chemical increased. A few plants survived in the plots which did not reach maturity at the expected time. Bulbing and maturity were delayed by about twenty days. These observations agree with those of Bucha (13). Bucha and Todd reported that initial effect caused by 3-(p-chloro phenyl)-1, 1-dimethylurea is leaftip dieback beginning on the older leaves. This was followed by progressive chlorosis and retardation of growth ending in death of the plant. Muzik et al. in 1954 (46) studied the effects of monuron on the absorption, translocation, and mechanism in plants and reported that the primary toxic action of this compound is on the aerial portion of the plant.

b. CDAA: There was no damage to the crop at the 6 lb and 8 lb and 9 lb/A level of application (Fig. 2). At the 10 lb/A level of application, a few plants turned chlorotic and some showed epinasty (Fig. 3). Since this appeared in isolated spots, and the percentage of such affected plants were low, it is believed that this may have been due to the excessive spray of the chemical at these locations on the plant. Plants were more vigorous in growth than plants in the hand-weeded and unweeded plots. It could be said that an application of CDAA at 8 lb/A was effective in controlling weeds without damage to the onions. This is in agreement

Fig. 2.--Plot treated with CDAA at 9 lb/A showing good weed control.

Fig. 3.--Plot treated with CDAA at 10 lb/A showing good weed control. Some plants turned chlorotic.

with the observations made by Noll in 1959 and Warren in 1962 (48,74), and Nylund et al. (53), 1962.

Noll reported on the chemical weeding of set and seeded onions grown in mineral soil. He stated that in the pre-emergence treatments CDAA was better than CIPC, and at 8 lb/A gave better weed control than CIPC at 9 lb/A.

c. CDAA + TCBC: Plants turned chlorotic on the second day after application, the intensity being greatest in plots that received the highest rate of application. The stems became weak and the plants lodged. Some of the stems and leaves had a twisted and crinkled appearance. All these effects were found to disappear within a week to ten days, the recovery being quicker in the sprinkler irrigated plots. By the 30th day when bulb initiation was about to take place, the chlorotic appearance completely disappeared and the plants were normal. The weed control was excellent except at 6 lb/A (Fig. 4).

The more rapid recovery of plants treated with CDAA + TCBC in sprinkler irrigated plots may be due to:

(1) the four hour period of irrigation leached the compound to the lower layers of the soil;

Fig. 4.--Plot treated with CDAA + TCBC at 6 lb/A showing fairly good control of broad-leaved weeds and grasses.

(2) the compound on the plants could have been completely washed away by the sprinkler water.

d. CDEC: The effects of CDEC were almost similar to that of CDAA. There was no damage to the crop in any form at all rates of application. The stems showed a deep green colour and appeared to be superior to those in all other treatments. The stems were thicker in diameter and the bulbs also were larger. Weed control was poor at 8 lb/A (Fig. 5) and good at 10 lb/A (Fig. 6). This is consistent with the observations made by Freed (29). Freed stated that the deep green colour resulting from treatment with the carbamates is directly due to an increased amount of chlorophyll in the tissues. Treated plants contained from 19-28% more chlorophyll per unit leaf area or per gram of dry weight than untreated plants. Similarly the nitrogen content of the treated plants was higher than the control.

e. Mixtures: Both the mixtures diuron + CDAA and diuron + CDEC gave fairly good weed control but were not better than either chemical alone. At the 1 lb/A application of diuron with either CDAA or CDEC, the onion plants showed effects similar to that of plants treated with diuron alone.

Fig. 5.--Plot treated with CDEC at 8 lb/A showing poor control of broad-leaved weeds. Boerhaavia diffusa Link not totally killed.

Fig. 6.--Plot treated with CDEC showing fairly good control of broad-leaved weeds and grasses.

Observations on the Germination and Growth of Local Weeds and the Damage Inflicted by Herbicides:

The major broad-leaved weeds in the onion growing tract of Jaffna are Boerhaavia diffusa, Amaranthus viridis, and Gynandropsis pentaphylla. Of the grasses Echinocloa colonum and Cyperus rotundus were common. Seeds of these weeds were germinated in the fields as well as in the laboratory to study their time of germination. The seeds of Boerhaavia diffusa were found to germinate in two to three days in the field, but took four to six days when placed on germinating dishes in the laboratory at room temperature (75 - 80°F). Amaranthus viridis took three days in the field and four days in the laboratory while Gynandropsis pentaphylla took five days to germinate in the laboratory and four days in the field. The difference in the number of days in the field from that in the laboratory may be due to unknown factors in the soil that influence germination.

The growth and population of these weeds varies with the season. They are quick growing and densely populated in the Maha Season, while slow growing and less densely populated in the dry Yala Season (Fig. 7). This may be due to the cool climate, ample availability of water, and less transpiration during Maha (see Table 11 for temperature and rainfall). It

Fig. 7.--A control plot heavily infested with Echinocloa colonum Link, Amaranthus viridis Link, and Boerhaavia diffusa Link during Maha Season.

was also observed that when plots were regularly irrigated during Yala, the germination of broadleaved weeds and grasses was much quicker; the cotyledoneus leaves of Boerhaavia diffusa and Amaranthus sp. were seen two days and three days respectively. This may be due to the availability of sufficient moisture and the high temperature which help in hastening germination.

Some of the Boerhaavia and Amaranthus seedlings that survived after the treatment were allowed to develop in order to study the amount of damage done by the herbicides. Most of these plants showed injury to leaves and stems. Sections of these treated stems were made and examined. Injury was found to have taken place in the cells of the epidermis and cortex. In areas where there was less damage, callus formation was observed. Also the cells adjacent to the damaged cells appeared to have reverted to meristematic activity. Internal injury was also found in cells of the phloem and vascular cambium. This was particularly seen in the stems that were woody. Often the internal injury in Amaranthus sp. was total.

Identification of Local Weeds:

The weeds present were classified into two categories. They were broadleaved and grasses.

Broadleaved Weeds:

Boerhaavia diffusa Link.	Amaranthus viridis Link.
Portulaca oleracea Link.	Acanthospermum hispidium DC.
Gynandropsis pentaphylla DC.	Ageratum conyzoides Vahl.
Tribulus terrestris Link.	Amaranthus spinosus Link.

Grasses:

Echinocloa colonum Link.	Dactyloctenium aegypticum Link.
Cyperus rotundus Link.	Setaria sp.

Other weeds present, but not in large numbers, were:

Commelina benghalensis Link.	Balainvillea latifolia DC.
Cleome viscosa Linn.	Tridax procumbens Link.
Leucas zeylanica R. Br.	Trichodesma indicum Br.
Synedrella nodiflora Gaertn.	Ocimum sanctum Link.
Acalypha indica Willd.	Heliotropium indicum DC.
Elusine indica (L.) Gaertn.	Aeura lanata Juss.
Chloris barbata Sw.	

Bulb Dormancy:

Bulb dormancy is an important factor in the use of herbicides on shallots. The sprouting of the bulbs when planted was very uneven up to the 55th day after harvest; the number of sprouts increasing as the age increased. Even germination could be observed by the fourth day if the seed bulb had rested for more than 65 days. There were instances when sprouting took place the second day after planting when the seed bulb had been stored for over a hundred days. This indicated that harvested bulbs should be rested for over 65 days from the time of harvest to the next planting if herbicides are to be used for the control of weeds.

Effects of Herbicide Treatments on Leaf to Bulb Ratio:

Table 12 shows the leaf to bulb ratio for the various treatments. The ratio is high in plots that received CDAA and CDEC and low in the control. The luxurious growth with a deep green colour of the leaves in CDEC and CDAA treated plots are reflected in the high ratio obtained. This has also showed increase in bulb weight.

TABLE 12.--Effects of herbicide treatments on leaf to bulb ratio.

Weed control treatment chemical/acre	Ratio
Hand-weeded	1 : 1.27
CDAA 6	1 : 2.50
CDAA 8	1 : 2.51
CDAA 10	1 : 2.30
CDAA + TCBC 6	1 : 1.91
CDAA + TCBC 8	1 : 1.75
CDAA + TCBC 10	1 : 1.50
CDEC 6	1 : 2.10
CDEC 8	1 : 2.32
CDEC 10	1 : 2.21

Organic Manure and Weed Population:

There was an increase in weed population with the increase in the levels of application of organic manure. The highest level (20 tons/A) has about 300% more weeds than the untreated plot. The prominent weeds were Boerhaavia diffusa, Amaranthus viridis, Echinocloa sp., Portulaca oleracea, and Setaria sp. The only possible explanation for the weed seeds to be carried in the organic manure is that cattle in Jaffna feed on these weeds when left in the free range and also are stall fed at night with some or all of the above said weeds included with their grass. The number of Amaranthus spinosus plants was found to be almost the same in all the plots. This appears to have not been transported by the cattle manure, the reason may be because they have thorns in them and are not eaten.

SUMMARY

Investigations were conducted in Ceylon to determine the hand-weeding costs of onions and savings which might be effected by the use of herbicides and also the effect of such herbicides on the crop of onion. Field experiments were carried out from September 1962 to January 1964. Shallots were grown in two types of land--a normally cultivated land and a land that had been fallow for over ten years--under two systems of irrigation. Time to weed in hours per acre, the cost to weed an acre hand-weeded and an acre under different herbicides was calculated. Yields under the various treatments were determined.

These studies provided the following conclusions:

1. The cost to weed shallots onions was reduced 35 to 44 percent with the use of herbicides under sprinkler irrigation and 11 to 30 percent under flood irrigation.

2. CDAA + TCBC at 10 lb/A proved to be the most effective herbicide under both sprinkler irrigation and flood irrigation. Under sprinkler irrigation the increase in yield was 86 to 104 percent and with flood irrigation the increase in yield was 104 to 108 percent.

3. When weeding was with herbicides alone, without any hand-weeding, the increase in yield was 76% under sprinkler irrigation and 112 percent with flood irrigation.

4. The best time of application of the herbicide is 3 to 5 days after planting onions.

5. Sprinkler irrigation is superior to flood irrigation.

6. There is a decrease in yield with an increase in weed population. The bulbs formed under high weed competition are normally unfit for the market.

7. Shallots should be rested for over 65 days from the time of harvest to the next planting if herbicides are to be used.

8. The weed population is directly proportional to the amount of organic manure applied.

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