STUDIES ON WEED CONTROL IN IRRIGATED ONIONS (*Allium cepa* L.) IN NORTHERN NIGERIA

By

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C E R T I F I C A T I O N

This thesis entitled 'STUDIES ON WEED CONTROL IN IRRIGATED ONIONS IN NORTHERN NIGERIA' by Gabriel Chukwuka ORKWOR meets the regulations governing the degree of Master of Science of Ahmadu Bello University, Zaria, and is approved for its contribution to scientific knowledge and literary presentation.

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DEDICATION

This work is dedicated to the blessed memory of my dearest mother the late Mrs. Maria Nkwo Asogwa Orkwor who answered the Lord's call on September 15th, 1975 when I was about to start this study. She taught me how to preserve onion bulbs in dry river sand for longer than eight months.

Mummy, it is just too late by five years and a half for me to have shared my experience with you on my studies and findings on onions.

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Chapter I

INTRODUCTION

Onion (Allium cepa L.) belongs to the sub-family Alliaceae. This plant is widely distributed in the northern hemisphere, especially the Union of Soviet Socialist Republics. Different opinions have been expressed as to its origin, with Middle Asia, the East Asian countries and the Mediterranean regions as the possibilities (Purseglove, 1972). Although it was originally a long-day plant and best suited to the temperate regions of the world, tropical cultivars have been developed through breeding and selection. Presently onion is cropped under all climates and in almost every part of the world.

Onion is the world's second most important vegetable surpassed only by tomatoes (Grubben, 1977). Global production of onions in recent years has risen from an average of 15.2 million metric tons per annum, during 1969-71 to 18.1 million metric tons in 1977 (Anon., 1978). At this same period, the United States of America was the largest producer of onions, followed by Japan, Spain, Egypt, Turkey and Italy, in that order (Jones and Mann, 1963). During the same period, Egypt was the world's leading exporter, of onions followed by the Netherlands, Spain, Italy and the U.S.A. while the United Kingdom was the largest importer.

closely followed by West Germany (Jones and Mann, 1963).

In Nigeria, onion is grown all over the country but the bulk of the production is done in the Northern Guinea and the Sudan ecological zones, between latitudes 10° and 13°N. The crop is produced by subsistence farmers in scattered holdings on fadama low-lands, along river banks and at irrigation sites during the dry season from October to March. Production surveys conducted by Inyang (1966) showed Sokoto, Kano, Zaria, Plateau, Bauchi and Borno to be major producing areas (Fig. 1). Rain-fed crops of onions in these areas have been grown with little success because of pests and disease problems associated with the conditions of high humidity during the wet season (Inyang, 1966).

In Nigeria, onion is probably the most frequently used vegetable and it is in constant demand all the year round. In addition to its food qualities and medicinal properties, onion is grown primarily for use in food flavouring. The aroma is due to allyl oils and organic sulphur compounds mostly the n-propyl disulphide in the bulb (Jones and Mann, 1963). These chemical compounds determine the quality of a particular variety of onions. This vegetable is prepared in several ways for consumption. Both mature and immature bulbs are eaten, either raw,



FIG1 : MAP OF ECOLOGICAL ZONES OF NIGERIA SHOWING MAJOR PRODUCTION AREA OF ONIONS AND IRRIGATION DAMS.

cooked or fried. The bulbs could be cut into slices, shredded or ground with pepper and tomatoes to prepare sauces, soups or stews. Recently the green leaves and the white leaf-bases prior to bulb formation are served raw in salads. Such immature plants are popularly known as 'spring onions' and are grown in market gardens in urban areas for city dwellers.

The present production rate of onion is grossly inadequate for the ever-increasing local demand. Lack of country-wide survey and available production statistics of this crop makes it almost impossible to quantify (i) areas under this crop, (ii) average yields per hectare and (iii) net profits realised by local farmers. The estimated yield of 12.0 tons per hectare reported by Inyang (1966) and Green (1971a) for Nigeria compared well with the world yield average reported by Purseglove (1972). This estimate was, however, far below the U.S. yield average which was estimated at 30 - 34 tons per hectare (Purseglove, 1972). It is possible, however, to raise yields to 45 tons per hectare or more by adopting improved husbandry practices in northern Nigeria (Green, 1971b).

A number of factors are known to be responsible for the low yields of onions currently obtained by farmers in Nigeria. Prominent among these is the inability of

of the local farmers to combat diseases and pests especially weeds. Olunuga and Akobundu (1980) observed that the inability of farmers to cope with excessive weed growth is associated with the use of primitive control methods of hand-pulling and hoeing. The traditional hoe-weeding presently used in this crop by local farmers is not only expensive, high labour-demanding, strenuous and limited to small-scale production but aslo liable to cause mechanical damage to the shallowly placed roots and bulbs with consequent yield reduction. Onion is a sensitive crop and a poor compeitor with weeds. It is susceptible to weed competition for most part of its growing season. Onion bulb yields are enormously reduced by weeds if not timely controlled. Although there are no available figures to show these losses in Nigeria, such losses range from drastic reductions to total crop failure in extreme cases.

The need arises, therefore, for an alternative method of weed control in onion, especially by the use of chemicals. A very suitable method, devoid of the problems associated with hoe-weeding will stimulate large-scale production, higher yields per unit area and thus increase the supply of this vegetable crop to meet the ever increasing demand.

This research was therefore conducted with the following

objectives:

1. To identify weeds infesting onion fields at Samaru, New Irrigation Site of I.A.R. and at Kadawa, Irrigation Research Station.

2. To study the effectiveness of herbicides for weed control in transplanted irrigated onions.

3. To compare the performance of herbicides with the traditional method of hoe-weeding and assess the extent of yield losses due to associated weeds during the growing period of onions.

4. To suggest suitable herbicides for onion production in northern Nigeria.

Chapter II

REVIEW OF LITERATURE

In agriculturally advanced nations of the world, various herbicides have been successfully used to control weeds in onions. In dealing with a sensitive crop like onion, crop tolerance is a major factor for consideration in choosing herbicides for selective weed control. Other factors like method of application, rates of herbicides, crop growth stage and weather conditions at the time of application as well as soil type determine onion tolerance to a particular herbicide. The available literature on the use of the herbicides selected for control of weeds in onions in this work is reviewed.

A. Chlorthal-dimethyl[1]

Chlorthal-dimethyl applied pre-transplant at 11.8 kg/ha[2] was very effective in the control of weeds, particularly grasses, in onions at Samaru (Green, 1972).

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[1] Chemical names of herbicides are given in Appendix A.

[2] All herbicide rate are given on active ingredient (a.i) basis.

He observed no crop injury and the yield obtained with this treatment was comparable to the hoe-weeded control. This herbicide applied pre-transplant at 11.5 kg/ha also gave the best control of grasses in onions in Argentina (Boy, 1973). In Canada, Dion (1974) observed that chlorthal-dimethyl applied pre-emergence at 10.0 kg/ha prevented the germination of weeds for one month in onions grown on a sandy-loam soil. Noll (1975) obtained good weed control in onions sown on silt-loam soil in Pennyslvania, USA using chlorthal-dimethyl pre-emergence at 11.2 kg/ha alone or followed by methazole at 3.4 kg/ha applied 50 days after sowing. In a later study, he reported (Noll, 1978) that chlorthal-dimethyl at this rate was the only herbicide that did not injure onions amongst several herbicides tried. Lower rates of chlorthal-dimethyl have also been used to obtain excellent weed control in onions. For example, Selleck and Sanok (1978) reported excellent weed control in transplanted onions with chlorthal-dimethyl applied pre-transplant at 6.7 kg/ha on sandy-loam soils in Long Island, USA. Kempen (1975) reported from California, USA that chlorthal-dimethyl at 8.9 kg/ha was as effective as 15.7 kg/ha. Thus, onions showed a wide range of tolerance for this herbicide and lower rates could be used to achieve the same results

with reduced costs on the herbicide. Other workers have also reported effective weed control in onions with chlorthal-dimethyl (Tanaka and Romanouski, 1972; Toth et al, 1973; Duranti and Bobo, 1977; Fokina et al., 1978).

The persistence of chlorthal-dimethyl in the soil with prolonged residual activity for periods longer than six months have been reported by Walker (1978), Spencer and Huges (1978), Verity (1978) and Roberts et al. (1978). This soil-acting herbicide is known to be adsorbed by organic matter and does not leach in all soil types (Anon, 1979b).

Chlorthal-dimethyl has also been found very effective in controlling weeds in onions when mixed with other herbicides in pre-emergence applications with no observable crop injury. Spencer and Hughes (1978) observed that a mixture of chlorthal-dimethyl at 4.5 kg/ha plus propachlor at 4.4 kg/ha gave better control of weeds in onions than the standard application of either of the herbicides. Roberts et al. (1978) have also reported that addition of chlorthal-dimethyl at 3.0 to 6.7 kg/ha to a standard pre-emergence application of propachlor at 4.4 kg/ha gave improved weed control with no crop injury on spring-shown bulb onions, under sandy-loam soils in Britain. In this study, some broad-leaved weeds like Solanum nigrum L. and

Chenopodium spp. that were relatively tolerant to propachlor alone were reported to be controlled. A report from Kirton, U.K. (Anon, 1979a) described a mixture of propachlor and chlorthal-dimethyl as the best pre-emergence treatment in autumn-sown bulb onions.

B. Fluorodifen

Fluorodifen at 3.0 kg/ha applied pre-transplant was found promising for the control of the weeds in transplanted onions on a sandy-loam soil at Samaru, Nigeria (Green, 1972). Zahran et al. (1971) found a combination of fluorodifen at 1.7 and methazole at 1.1 kg/ha as one of the best treatments tested for the control of weeds in onions on a loamy-clay soil in upper Egypt. This treatment was only surpassed by a combination of chlorthal-dimethyl and methazole.

C. Oxadiozon

Oxadiozon is a soil applied herbicide that has been widely used for selective control of weeds in transplanted onions. The herbicide kills weeds by contact with the young shoots that may grow through the treated zone (Gary et al., 1974). Oxadiazon is believed to have a broad spectrum activity on a number of broad-leaved and grassy weeds.

This herbicide has a very low solubility in water and could remain on the soil surface where herbicidal activity persisted for several months (Chevrel and Tyrrell, 1973). Leefe (1973) obtained effective control of weeds in sweet spanish onions with oxadiazon applied pre-emergence at 2.2 kg/ha. Sanok and Weber (1975) also got good results with this herbicide at 1.0-4.5 kg/ha applied pre-emergence on a sandy-loam soil in Long Island, USA. In Canada, a good control of weeds in onions was reported with oxadiozon at a total dose of 1.68 kg/ha in three or two split applications (Anon, 1974c). Phytotoxicity occurred when this rate was exceeded. Randhawa (1977) reported good weed control in onions with oxadiazon at 1.0-1.5 kg/ha pre-emergence with an increase in bulb yield. He did not observe any significant difference in yield between oxadiazon at 1.5 kg/ha and two hand-weedings. In the same study, a rate of 1.0 kg/ha of the herbicide applied post-emergence, about 40 days after transplanting gave good control of especially broad-leaved weeds. Sandhu and Randhawa (1978) also obtained excellent weed control in onions, especially of broad-leaved weeds, when oxadiazon was applied pre-emergence at 2.0 and 3.0 kg/ha on a loamy-sand soil.

D. Methazole

Methazole is a broad spectrum herbicide that has been widely used for the control of weeds in arable crops, including onions. Some of the initial work with methazole in onions was carried out by Griffith and Baker (1970) who recommended rates of up to 2.2 kg/ha to be applied when the onion seedlings have reached at least 2-leaf stage. Reports from Kirton, U.K. (Anon, 1974a) indicated that the application of methazole at 2.2 kg/ha at crook-stage; that is before the 2-true leaf stage of onion seedlings damaged the crop on a sandy-loam soil with a reduction in yield. Rates of 1.25-2.5 kg/ha gave excellent weed control with no crop damage when the herbicide was applied after the 2-leaf stage on the same soil. The findings of Griffith and Baker (1970) on the dosage of application of methazole have been confirmed by such other workers as Lake and Griffith (1971), Edwards (1972), Baker and Edwards (1972), Roberts and Bond (1972), Wilson (1977) and Duranti and Bobo (1977).

Heavy soils are known to take higher doses of methazole without crop injury when applied at the correct growth stage of onions. On the other hand, Lake and Griffith (1971) observed that rates of up to 2.0 kg/ha of methazole at 2-3-leaf stage were tolerated by the crop and gave good weed control even on mineral soils, but its effectiveness was doubtful on soils with organic matter content of more than 40%. Loamy soils have also been known to take as much as 3.6 kg/ha of methazole without any injury to onion crop. In contrast, crop damage was reported in Australia following an application of this chemical at rates above 1.1 kg/ha on a light sand (Plumbe, 1974). Cognet and Muller (1972), on the other hand, reported that the rate of up to 2.6 kg/ha was safe for the crop; and higher rate was required to control tougher grasses like Echinochloa crusgalli (L) Beauv. and Digitaria sanguinalis L. The results reported from Australia by Rowell and Badley (1975) confirmed those of Cognet and Muller (1972). Other workers who reported good weed control with methazole in onions include Furness (1971) in Lebanon, Kovacs et al. (1971) in Italy, Zahran et al. (1971) in Egypt, Aelbers and Bastiaansen (1972) in the

Netherlands, Formigoni (1972) in Italy, Duranti and Bobo (1977) in Italy, Wilson (1977) in New Zealand and Anonymous in the U.K. (1979a).

Persistence of methazole in the soil has been found to vary with the organic matter content of the soil. Edwards (1972) observed that methazole remained effective or up to 12 weeks in mineral soils, 10 weeks on soils of 5-20% organic matter content and only 6 weeks on soils with more than 50% organic matter. This property of methazole could be advantageous in soils with low organic matter where prolonged residual activity of this herbicide will give longer duration of weed control.

High ambient temperatures at the time of application of methazole did not affect on the onion tolerance to this herbicide (Rowell and Badley, 1975). Cold weather reduced the effect of methazole as indicated in reports from Tasmania, Australia (Anon, 1974b).

Crop-growth stage, soil type, weed species to be controlled and temperature, are important factors to be considered in determining effective and safe dosage of methazole (Lake and Griffith, 1971).

E. Chloroxuron

Chloroxuron is both soil and foliar active and is reported to be effective for the control of broad-leaved and grass weeds selectively in vegetable crops, including onions.

Ebner and Schuler (1964) reported good selective weed control in onions with chloroxuron applied post-emergence at 4.0-6.0 kg/ha in Switzerland. Roberts and Wilson (1964) also obtained good results with this herbicide at 3.0-4.0 kg/ha with a post-emergence application. These workers stressed the importance of applying the herbicide after the crook stage of onions. It was reported that the root uptake of chloroxuron could cause crop injury (Green, 1972). Hartfield and Sweet (1975), reported good onion seedling tolerance to chloroxuron at 1.0-3.4 kg/ha after 2-leaf stage on muck soil in New York, USA. They further reported that placement of chemical adjacent to plant, instead of over all foliage application, caused crop injury. Tanaka and Romanouski (1972) and Sweet[1] also obtained

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[1] Sweet, R. D. (Personal communication) Vegetable Crop Department, Cornell University, Ithaca, New York, 1979.

good results with this herbicide in transplanted onions. Kameneva and Penkov (1975) also reported excellent weed control with chloroxuron and aziprotryne but observed that chloroxuron reduced sugar and ascorbic acid content of onions. Leela (1977) on the other hand, reported that a combination of nitrofen and chloroxuron at 1.0 kg/ha applied 10 days before transplanting of onions gave a yield increase of 23% and the highest sugar percentage.

F. Bentazone

Bentazone is a foliar active herbicide which kills target species by inhibiting Hill reaction and photosynthesis. Its ability to control a number of broad-leaved weeds particularly Solanum nigrum and sedges, especially Cyperus spp., selectively in many large seeded legumes has been reported (Anon, 1979c). It has not been widely used in onions as in other vegetables for the control of weeds. However, Mahadeva and Reesor (1973) reported that bentazone at 1.0 kg/ha applied pre-emergence in Alberta, Canada was effective for control of annual broad-leaved weeds in autumn-sown onions.

Wilson and Scheffer (1978) also used bentazone to control weeds successfully in onions in New Zealand. The successful use of bentazone at 0.75 kg/ha applied post-emergence has also been reported in Belgium (Anon, 1979d).

G. Linuron

Linuron is a soil applied herbicide exhibiting post-emergence activity and has been used in combination with other herbicides for the control of especially grasses in arable crops including vegetables. Duranti and Bobo (1977) reported a successful weed control using linuron in transplanted onions on a sandy soil in Italy. Deuber et al. (1977) also controlled weeds effectively in onions with linuron at 1.0 kg/ha before and at 0.75 kg/ha after weed emergence in Brazil. Linuron was reported to be an effective and economic herbicide for weed control in onion when applied in split doses (Whitlock, 1977).

Chapter III

MATERIALS AND METHODS

A. Experimental Sites

Two field experiments were conducted at the Irrigation site of the Institute of Agricultural Research, Samaru, Zaria and at the I.A.R. Irrigation Research Station, Kadawa, in the Kano River Project during the dry season 1979-80. Samaru is located in the Northern Guinea Savanna, north-west of Zaria (11°, 10'N, 07° 38'E) while Kadawa is in the Sudan zone south-west of Kano (11° 39'N, 08°E) as shown in Fig.1.

The soil at each location is sandy-loam, well drained and low in organic matter content (Table 1). The field at Samaru had been left fallow during the preceding wet season and sown with millet in the 1978-79 dry season. The Kadawa field was put under millet during the wet season that preceded the experiment.

B. Treatments and Experimental Design

A total of 15 treatments were investigated as shown in Table 2. Treatments were arranged as a randomized complete block design in four replications.

Table 1. Physico-chemical analysis of experimental soils at Samaru and Kadawa, 1979-80.

Physico-chemical composition	Samaru	Kadawa
Clay content (%)	10.0	9.3
Fine silt (")	7.3	2.7
Coarse silt (")	35.3	28.0
Fine sand (")	34.9	55.2
Coarse sand (")	12.4	4.7
Organic carbon (%)	0.68	0.34
pH (water)	4.8	6.0
Exchangeable cations		
Exch. Na^{+} (m.eq/100 g soil)	0.06	0.05
Exch. K^{+} (")	0.16	0.12
Exch. Ca^{++}+ Mg^{+}(")	2.4	3.2
Cation exch. capacity (m.eq/100 g soil)	6.3	6.0
Base saturation (%)	41.3	50.0

Table 2. Herbicides evaluated for weed control in onions at the Institute for Agricultural Research, Samaru and the Irrigation Research Station, Kadawa, during 1979-80 dry season.

Herbicides	Formulation	Rate (kg a.i./ha)	Time of Application	
			Samaru	Kadawa
Pre-transplant				
Chlorthal-dimethyl	75% WP	12.0	2 DBT	2 DBT
Fluorodifen	300 g/l ec	1.5	2 DBT	2 DBT
Fluorodifen	300 g/l ec	3.0	2 DBT	2 DBT
Oxadiazon	250 g/l ec	1.0	2 DBT	2 DBT
Oxadiazon	250 g/l ec	2.0	2 DBT	2 DBT
Post-transplant				
Chloroxuron	50% WP	2.0	25 DAT	32 DAT
Chloroxuron	50% WP	4.0	25 DAT	32 DAT
Chloroxuron	50% WP	2.0 fb 2.0	25 and 55 DAT	32 and 56 DAT
Methazole	75% WP	1.0	30 DAT	32 DAT
Methazole	75% WP	2.0	30 DAT	32 DAT
Bentazone + Linuron	480 g/l ec + 50% WP	1.2 + 0.4	30 DAT	30 DAT
Bentazone + Linuron	480 g/l ec + 50% WP	1.2 + 0.8	30 DAT	30 DAT
Controls				
Hoe-weeding (as and when necessary as the farmer does)				
Weed-free	-	-	-	-
Unweeded	-	-	-	-

DBT: Days before transplanting; DAT: Days after transplanting; WP: Wettable powder; ec: Emulsifiable concentrate; fb: Followed by.

C. Nursery Management

The local variety of onion, 'Kano red' was used at both locations. This is an important variety of onion grown in Nigeria. Although it is known to have high tendencies for bolting, it is well adapted to the local conditions and has higher dry matter content than some exotic varieties tested in northern Nigeria (Green, 1971b).

The nursery was located at Samaru. Seedlings were raised in basins 1.0 x 6.0 m. Organic manure (Cow dung) was supplied at 10 tons per hectare and this was supplemented with inorganic fertilizer NPK (10: 20: 10), at 250 kg/ha. Seeds were sown 1.5 cm deep in 20 cm rows and covered lightly with river sand and mulched with dry grass. Seedlings emerged seven days later and a germination of over 98 per cent was recorded. Up to the end of the third week after sowing, sprinkler overhead irrigation was used to supply water in the nursery during the mornings. This was supplemented with watering cans in the evenings. However, from the fourth week onward, flood irrigation was used. Plants were in the nursery for eight weeks, from October to December, 1979 before transplanting in December, 1979 (Plate 1).



Plate 1. Nursery: Seedlings were raised at Samaru October - December, 1979.

E. Transplanting

Seedlings were transplanted at eight weeks after sowing in the nursery on the 18th and 19th December, 1979 at Samaru and Kadawa experimental plots, respectively.

Crops were spaced at 15 cm between plants in rows 20 cm apart to get a plant population of 333333 plants/ha. Each plot carried 216 seedlings. Transplanting was completed before noon at each location to ensure uniform establishment, after which the fields were flood irrigated.

F. Herbicide Application

Pre-transplant herbicides were applied two days before transplanting and the plots were flood irrigated the same day at each location. A CP3 knapsack sprayer was used with a deflector nozzle covering a swath of 90 cm at a pressure of 2.1 kg/cm^2 to deliver 220 l/ha of spray solution. The post-emergence herbicides were applied when most weeds were above 2-leaf stage on treatment basis. The application was either done early in the morning or late in the evening to avoid strong wind and resultant drift. Post-emergent herbicides were applied two days after irrigation.

G. Irrigation

Plots were irrigated twice a week for the first three weeks after transplanting because of dry atmosphere and low relative humidity observed during this period of the growing season at both locations (Appendices C1-C4). After ; the first six weeks when seedlings were well established, irrigation frequency was reduced to once a week for the next six weeks, after which plots were irrigated at ten-days interval for three weeks. Irrigation was stopped three weeks before harvest to allow the plants to mature properly. Two days to final harvest, light irrigation was applied to facilitate bulb harvest.

H. Pest Control

Routine check and spray of malathion against thrips was carried out as necessary, at both locations. Ant holes detected were sprayed with aldrin dust.

I. Data Collection

1. Meteorological data

Meteorological data collected at Samaru included air temperature, soil temperature at 5 cm depth, rela-

tive humidity, evaporation, sunshine hours and dew-point. Due to breakdown of meteorological equipment at Kadawa, only air temperature was recorded.

2. Weed and Crop data

At Samaru, the following data were collected from the net plots: weed cover, crop vigour score, number of bolters, average number of leaves, height of plants, oven-dry weed weight, air-dry bulb yield at 18 weeks after transplanting, fresh bulb plus leaves, and dry leaves. The crop and weeds were also removed from the sampling area at 13 weeks after transplanting with the following data collected: fresh weight of bulbs + leaves, air-dry bulbs, fresh and dry weed weights and bulb diameter. In addition, stand counts were taken at the time of sampling from the sampling area and at harvest from the net plot. Data were collected on dates given in the respective tables.

At Kadawa, the same data as at Samaru were collected but on different dates as indicated in the respective tables. Bulb diameter was not measured at Kadawa. The crop vigour score was taken only once against twice at Samaru.

The method of data collection on crops and weeds was as follows:

(a) Weed cover score: Weed cover score was based on a scale 0-10, where plots completely covered by weeds were assigned 10 while those without weeds were assigned 0. Between these extremes, scores were given to reflect the extent of weed coverage of each experimental plot at both locations. Weed cover score was taken 4 and 12 weeks after transplanting at Samaru and 4 and 16 weeks after transplanting at Kadawa.

(b) Crop vigour score: A scale of 0-10 was used to rate the crop vigour. The plot with the most vigorous plants was assigned 10 while 0 was to be given to completely dead plants. Crop vigour score was taken at 4 and 12 weeks after transplanting at Samaru and 4 weeks after transplanting at Kadawa.

(c) Weed collection:

(i) Hoe-weeded plots: Weeds were removed, using locally made special onion hoes, when the weeding was due from the net plots. Only the above-ground weed growth was collected, washed, weighed fresh and oven-dried for dry weight determination.

Samaru trial received five hoe-weedings in the hoe-weeded plots while six hoe-weedings were done at Kadawa in this treatment to simulate farmers method of control.

(ii) Weed-free plots: Weeds were removed from the net plots by hand-pulling with minimum disturbance of the soil. They were washed and weighed fresh and oven-dried.

(d) Plant height: Centrally placed 24 plants in the net plot were measured 11 weeks after transplanting at Samaru while the height measurements at Kadawa were taken at 12 weeks after transplanting.

(e) Leaf count: The same 24 plants from the centre of the net plots were used. Their leaves were counted and the average per plant recorded as leaf production capacity.

(f) Bulb yield: Bulb yield was sampled from an area 0.45 m^2 outside the net plot within the basin at 13 and 16 weeks after transplanting at Samaru and Kadawa, respectively, and the following data collected: bulb + leaves and bulb yield.

Final harvest of the crops was done from the net plots 18 and 19 weeks after transplanting at Samaru and

Kadawa respectively with the following data collected: bulb + leaves, bulb yield and dry leaf yield.

J. Statistical Analysis

Data were statistically analysed according to the methods described by Little and Hill (1972). Correlation analysis was also computed. Least significant differences were calculated at 5 and 1 per cent levels of probability for comparing differences between treatments. Data for all non-normally distributed variables including weed-cover score, weed weights and crop vigour score were transformed using $\sqrt{x + 0.5}$.

Chapter IV

RESULTS AND DISCUSSION

A. Samaru Experiment

The experimental area at Samaru was infested mainly with annual grasses and a number of broad-leaved weeds. The grasses were Axonopus compressus (SW) Beauv., Chloris pilosa Schum., Dactyloctenum aegyptium (L.) Beauv., Digitaria horizontalis Willd. and Eleusine indica L. The major broad-leaved weeds at Samaru were Euphorbia heterophylla L., Euphorbia hirta L., Portulaca oleraceae L., Solanum nigrum L. and Talinum triangulare (Jacq.) Willd. Cyperus rotundus L. was the only sedge observed. A complete list of the weed species found at the experimental site is given in Appendix B.

Treatment effects on crop and weeds were monitored regularly throughout the growth period of the crop (Plate 2). The results of the effects of herbicides on weeds and growth and yield of onions at Samaru experimental location during the 1979-80 dry season are discussed.

1. Effects on weeds

(a) Weed cover score: The data taken[1] at 4 and 12 weeks after transplanting of onion seedlings are given in Table 3.

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[1] Scores were based on a scale of 0-10 as described in Chapter III.



Plate 2. A cross section of the experimental site at Samaru during the dry season 1979-80.

Table 3. Effects of various rates of herbicides on weed growth in onions at Samaru during the 1979-80 dry season.

Treatments		Weed cover score				Weed weight (t/ha)		
		4 WAT		12 WAT		13 WAT		18 WAT
Herbicide	Rate Kg a.i./ha	t	0	t	0	t	0	0
Pre-transplant								
Chlorthal-dimethyl	12.0	1.2	1.1	2.0	3.3	1.1	0.7	2.6
Fluorodifen	1.5	1.1	0.7	2.5	5.7	1.5	2.0	4.7
Fluorodifen	3.0	1.3	1.6	2.5	5.8	1.2	1.0	5.2
Oxadiazon	1.0	1.0	0.6	2.1	4.0	0.9	0.6	3.7
Oxadiazon	2.0	0.7	0.1	1.4	1.5	0.7	0.0	1.1
Post-transplant								
Chloroxuron	2.0	2.4	5.4	3.0	8.3	1.9	3.5	9.2
Chloroxuron	4.0	2.2	4.6	3.0	8.4	2.3	4.9	8.6
Chloroxuron	2.0 fb 2.0	2.4	5.7	3.1	9.4	2.2	4.3	9.6
Methazole	1.0	2.7	6.6	3.2	9.7	2.7	6.8	9.9
Methazole	2.0	2.4	5.3	2.8	7.6	1.8	2.7	6.6
Bentazone + linuron	1.2 + 0.4	2.5	5.7	3.1	9.2	0.9	4.7	8.8
Bentazone + linuron	1.2 + 0.8	2.7	7.0	2.9	7.9	0.7	3.1	7.3
Controls								
Hoe-weeded	-	2.4	5.5	0.7	0.0	0.7	0.0	0.9
Weed-free	-	2.4	5.4	0.7	0.0	0.7	0.0	2.2
Unweeded	-	2.6	6.4	3.2	10.0	2.4	5.2	9.0
LSD (.05)		0.45		0.29		0.49		3.44

t = transformed data

0 = original data

WAT = Weeks after transplanting

All the pre-transplant herbicides significantly reduced weed cover at 4 weeks after transplanting. The score taken at four weeks after transplanting showed that oxadiazon at both rates tested gave the best control of weeds. Weed score obtained with oxadiazon, chlorthal-dimethyl and fluorodifen at this first score 4 weeks after transplanting were comparable. The next best herbicide to oxadiazon was chlorthal-dimethyl followed by fluorodifen. No weeding had been done on the hoe-weeded and weed-free controls because the hoe-weeded plots were not considered due for weeding when this score was taken. Weed removal in the weed-free treatment was to be done by hand-pulling. Even though coverage in this treatment was fairly high at that time, the weeds were too small to be hand-pulled without disturbing the soil appreciably. Similarly, high weed scores were observed in the post-transplant herbicide treatments because chloroxuron was applied four days before the first weed cover score while methazole and bentazone plus linuron were applied one day before the score. The effects of these post-transplant herbicides were therefore not fully established and did not influence weed cover. At this first score, however, significant differences observed between unweeded control and the pre-transplant herbicides marked out the superiority of these herbicides.

The second score of weed cover was taken 12 weeks after transplanting and when all the treatment application had been completed. The score, therefore, provided a better estimate of the treatment effects on weeds than the first, although the pre-transplant herbicides still had significantly lower weed cover when compared with post-transplant herbicides leaving the plots almost weed-free (Table 3 and Plates 3, 4 and 5). Oxadiazon at 2.0 kg/ha had the least weed cover, chlorthal-dimethyl at 12.0 kg/ha and oxadiazon at 1.0 kg/ha were the next best while fluorodifen was the least effective among the pre-transplant herbicides. There was no difference between hoe-weeding and weed-free treatment inspite of the fact that at the time of the second weed cover score, there had been only three hoe-weeding operations as opposed to six weedings in the weed-free plots. (Plates 6 and 7).

(b) Weed weight : The effects of herbicides on the dry weight of weeds at Samaru are summarised in Table 3 and Figs. 2a and 2b. In general, weed weights showed similar trends to those observed under weed cover score. The dry weed weights at sampling 13 weeks after transplanting, and at final harvest, 18 weeks after transplanting, showed significant differences among the treatments. The pre-transplant herbicides gave significantly lower weed weights



Plate 3. Fluorodifen at 3.0 kg/ha gave excellent control of weeds 10 weeks after transplanting onion seedlings at Samaru.



Plate 4. Chlorthal-dimethyl, at 12.0 kg/ha kept the plot weed-free up to 11 weeks after transplanting at Samaru.



Plate 5. Oxadiazon at 2.0 kg/ha kept the plots weed-free up to 12 weeks after transplanting at Samaru.



Plate 6. Weed-free control at Samaru, after 6 weedings 12 weeks after transplanting.

as compared with the post-transplant herbicides. These post-transplant treatments did not differ in weed weights from the unweeded check. The magnitude of increased weed infestation was seen in the unweeded control (Plate 8), where weed weight was doubled in a period of five weeks between the sampling period and the final harvest (Table 3).

The pre-transplant herbicides gave significantly better weed control than the post-transplant herbicides used in this study. The latter did not control the weeds effectively, especially grasses. In most cases, weeds that emerged two weeks after the spray of post-transplant herbicides and those that had passed four-leaf stage before the spray were not controlled.

2. Yield attributes

The effects of herbicides at various rates on agronomic characters likely to affect the final bulb yield are summarised in Table 4.

(a) Crop vigour score: Early weed control obtained with the pre-transplant herbicides resulted in significantly higher crop vigour than that obtained with the post-transplant herbicide treatments, 12 weeks after transplanting (Table 4). The crop vigour with post-transplant herbicides was comparable to those of the hoe-weeded



Plate 7. Hoe-weeded control at Samaru after 4 hoe-weedings



Plate 8. Unweeded control, heavily infested with broad-leaved weeds especially Solanum nigrum L. and some grass weeds 10 weeks after transplanting at Samaru.

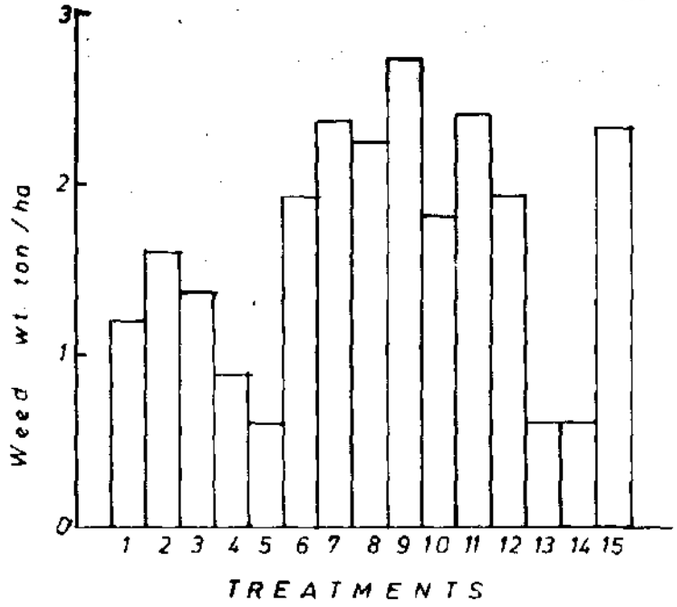


Fig. 2a: Dry wt. of weeds sample 13WAT onions at Samaru 1979-80 dry season

	TREATMENTS	Rate Kg a.i/ha
1	Chlorthaldimethyl	12
2	Fluorodifen	1.5
3	Fluorodifen	3
4	Oxadiazon	1
5	Oxadiazon	2
6	Chloroxuron	2
7	Chloroxuron	4
8	Chloroxuron	2fb2
9	Methazole	1
10	Methazole	2
11	Bentazone+Linuron	1.2+0.4
12	Bentazone+Linuron	1.2+0.8
13	Hoe-weeded	-
14	Weed-free	-
15	Unweeded	-

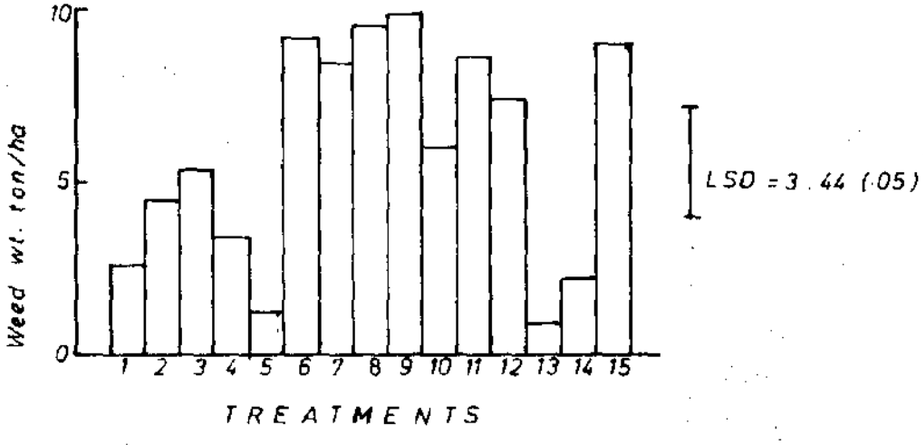


Fig. 2b: Dry wt. of weeds at harvest 18WAT onions at Samaru, 1979-80 dry season

Table 4. The effects of various rates of herbicides on yield attributes of onion at Samaru, during the dry season 1979-80.

Treatments		Crop vigour score 12 WAT		No. of leaves/ plant 11 WAT	Plant height 13 WAT (cm)	Bulb diame-ter 13 WAT (cm)	Bolted plants 6 WAT (%)	Stand at harvest (%)
Herbicide	Rate Kg a.i/ha	t	0					
Pre-transplant								
Chlorthal-dimethyl	12.0	3.0	8.8	12.5	48.5	4.9	68.8	98.8
Fluorodifen	1.5	2.9	7.7	10.6	44.3	4.9	84.2	96.9
Fluorodifen	3.0	3.0	8.3	10.3	44.6	4.5	80.9	94.9
Oxadiazon	1.0	3.1	8.9	10.6	44.0	4.8	68.8	99.1
Oxadiazon	2.0	3.0	8.3	9.7	46.6	4.6	63.8	99.7
Post-transplant								
Chloroxuron	2.0	2.7	6.7	11.6	47.4	3.8	80.9	93.6
Chloroxuron	4.0	2.7	6.6	10.8	45.8	4.0	66.3	96.9
Chloroxuron	2.0 fb 2.0	2.6	6.4	10.7	50.2	4.1	89.1	98.6
Methazole	1.0	2.6	6.3	10.3	46.2	3.9	67.1	98.2
Methazole	2.0	2.8	7.4	10.4	46.9	4.4	87.5	97.5
Bentazone + linuron	1.2 + 0.4	2.7	6.7	10.4	44.5	4.4	80.1	96.3
Bentazone + linuron	1.2 + 0.8	2.9	7.7	11.0	52.4	4.2	68.2	96.0
Controls								
Hoe-weeded	-	3.0	8.7	9.7	50.6	4.0	66.0	96.0
Weed-free	-	3.0	8.3	10.7	48.3	4.7	59.7	96.9
Unweeded	-	2.4	5.3	9.3	50.1	3.5	83.6	95.2
LSD (.05)		0.25		1.37	NS	0.63	NS	NS

NS: Non-significant.

and weed-free controls. A reduction of 20% in crop vigour was observed in the case of the unweeded control as compared to hoe-weeded treatment. Among the post-transplant herbicides studied at Samaru, mixture of bentazone at 1.2 plus linuron at 0.8 kg/ha gave the highest crop vigour which was significantly higher than that of the unweeded control. This was followed by the higher rate of methazole.

(b) Number of leaves: Significant differences were observed in the number of leaves produced by onions with various treatments, 11 weeks after transplanting. Chlorthal-dimethyl gave significantly higher number of leaves per plant as compared with other treatments including the controls with the exception of chloroxuron at 2.0 kg/ha. Although leaf production was found to be positively and highly correlated with bulb yield (Table 5), differences observed in number of leaf production were not sufficiently reflected in the final bulb yield. Visual observation showed that onion plants with fewer number of leaves had larger leaf sizes than those with greater number of leaves. These differences in leaf sizes were likely to have affected and pre-determined the number of leaves produced by the plants.

Table 5. Correlation analysis of some agronomic characters, yield of onions, weed cover score and weed weights at Samaru, during the dry season 1979-86.

Variables	'r' Values							
	2	3	4	5	6	7	8	9
1 Crop vigour score (12 WAT)	.279**	.526**	.878**	.671**	.206*	-.717**	-.513**	.090
2 Leaf production		.258*	.298**	.355**	.180	-.078	-.115	.004
3 Bulb yield (13 WAT)			.625**	.783**	-.118	-.314	-.304	-.048
4 Bulb yield at harvest				.713**	.129	-.716**	-.664**	.029
5 Bulb diameter (13 WAT)					-.055	-.378**	-.333**	.072
6 Plant height						-.139	-.111	-.082
7 Weed cover score							.750**	.132
8 Weed weight (Total)								.197
9 Bolter production								

** Significant at one per cent (P = .01)

* Significant at five per cent (P = .05)

(c) Plant height: No significant difference was observed among treatments in the height of onion plants at 13 weeks after transplanting (Table 4). Plant height did not show any correlation with bulb diameter, number of leaves or bulb yield at Samaru location.

(d) Bulb diameter: Chlorthal-dimethyl at 12.0 kg/ha, fluorodifen at 1.5 kg/ha and oxadiazon at 1.0 kg/ha produced significantly larger marketable bulbs than all post-transplant herbicides and the hoe-weeded control (Table 4). These results are largely in agreement with those of Green (1972) on chlorthal-dimethyl; Randhawa (1977) on oxadiazon and Zahran et al. (1971) on fluorodifen. The present study showed that pre-transplant herbicides such as chlorthal-dimethyl at 12.0 kg/ha, fluorodifen at 1.5 kg/ha and oxadiazon at 1.0 kg/ha increased bulb diameter by 25.5%, 22.5% and 20% over the hoe-weeded control respectively. Also at Samaru, bulb diameter of onion from post-transplant herbicides 13 weeks after transplanting were comparable to those of the hoe-weeded control, while weed infestation reduced bulb diameter by 25.5% in the unweeded control relative to the hoe-

weeded control. Methazole at 2.0 kg/ha and bentazone plus linuron mixture at 1.2 plus 0.4 kg/ha were the most promising among the post-transplant herbicides in bulb size. Bulb diameter at Samaru was found to be highly correlated with the final bulb yield of onions. The bulb size was also highly correlated with leaf production (Table 5).

(e) Number of bolters produced: It was observed that there was a variation in bolting percentage among different treatments six weeks after transplanting, but the differences were non-significant (Table 4). By 13 weeks after transplanting over 90% of onions had bolted in most of the treatments. 'Red Kano' onion cultivar used for the present study was reported to have high genetic tendencies for bolting (Green, 1971b). Seedlings of onions used for the field study were fairly large when they were transplanted after eight weeks of nursery. In addition to large sized seedlings, other factors such as uneven distribution of irrigation water, poor drainage and low temperatures (Montelaro and Times, 1956; Hanumantha and Purewal, 1957) have been reported to enhance bolting. Low temperatures of the cold dry harmattan periods prevalent during the growing period of the crop in this study (Appendices C1 - C3 and Figs. 3, 4 and 5) could

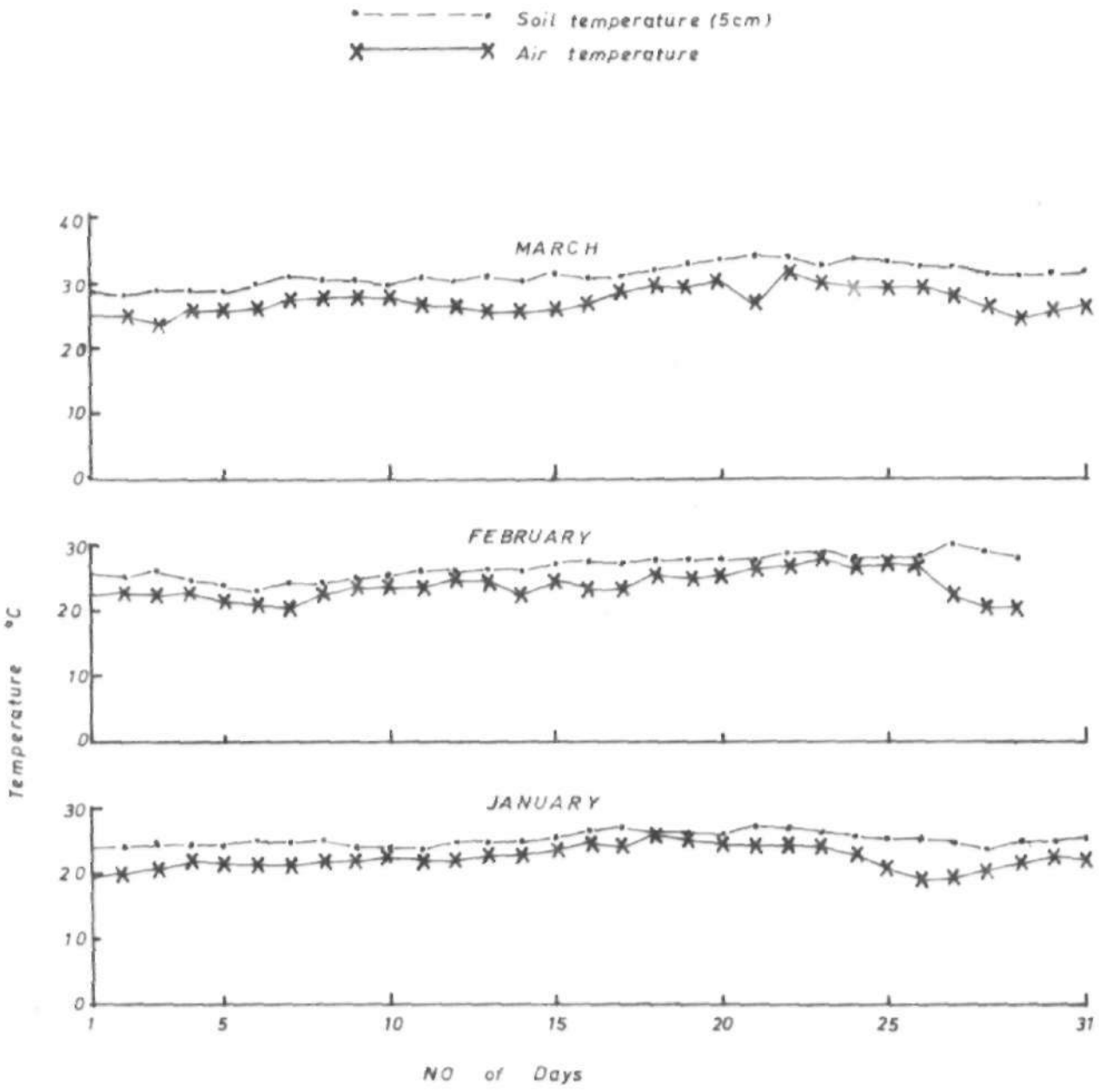


Fig3: Daily mean-Air and Soil (5cm) temperature at Samaru Research Farm (Jan — March 1980)
From Appendix (C1-C3)

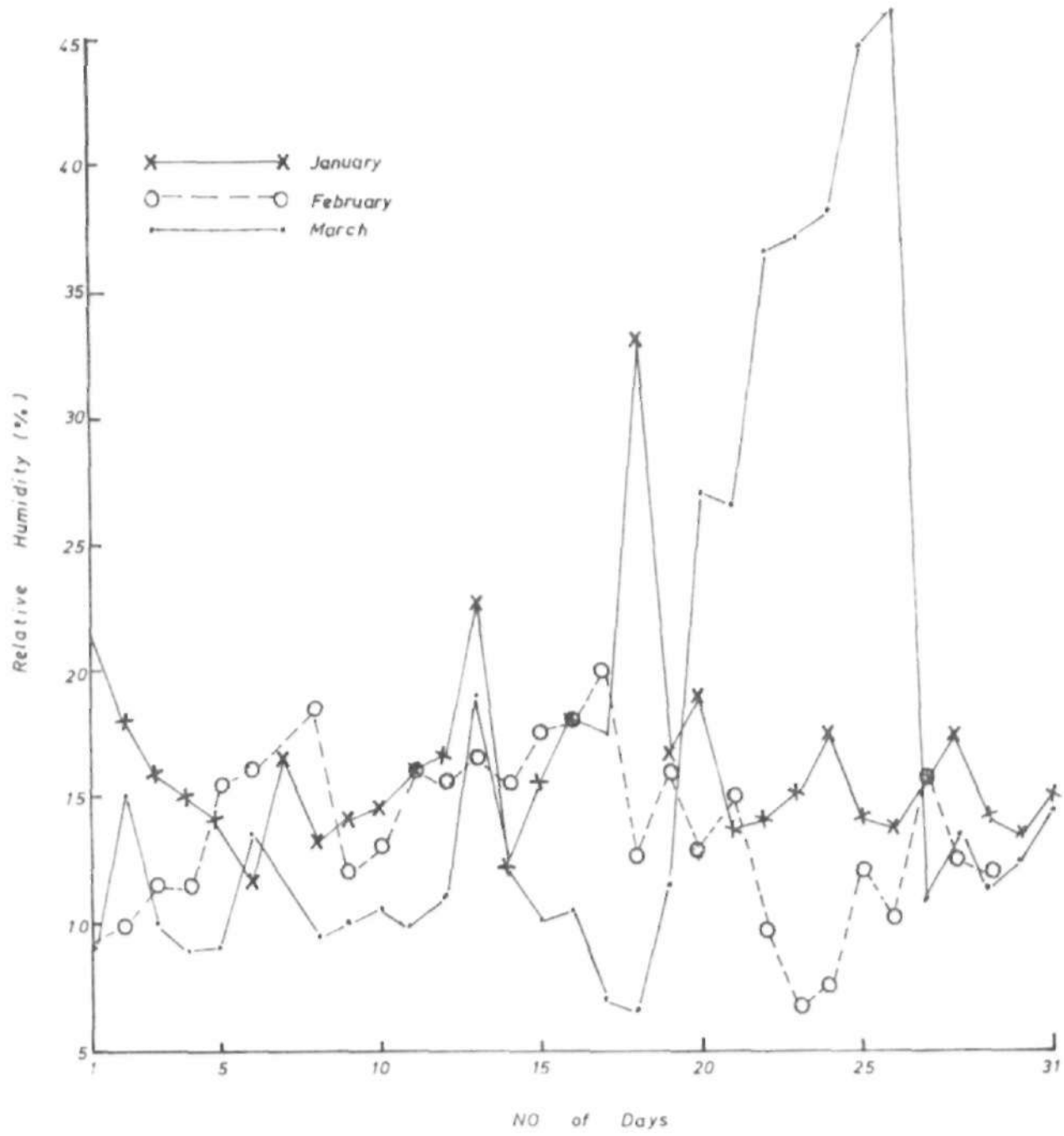


Fig 4 : Daily mean Relative Humidity at Samaru (Jan — March 1980)
From Appendix(C1 – C4)

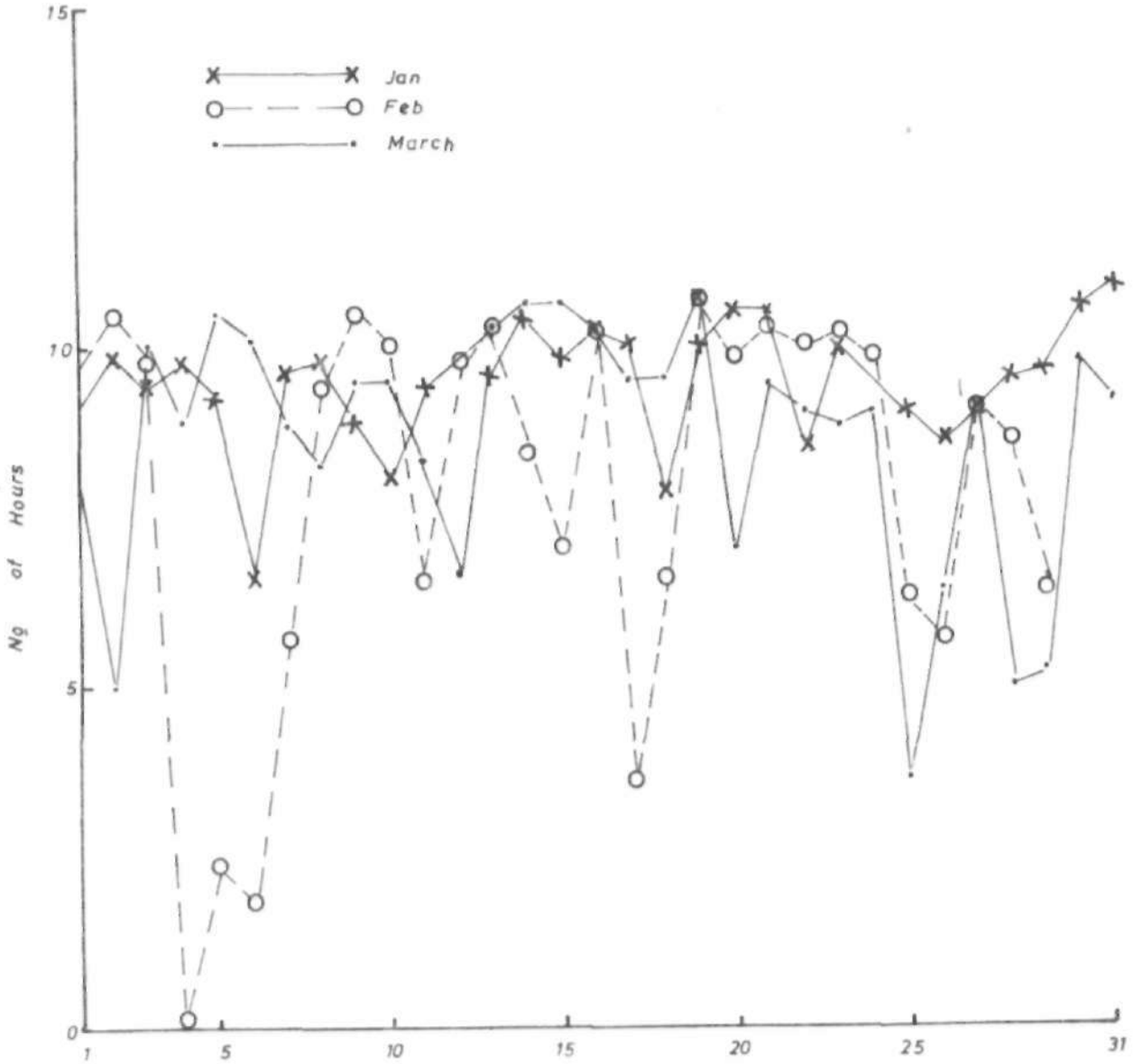


Fig.5 : Sunshine (hrs) at Samaru Research Farm (Jan — March 1980)
From Appendix (C1 – C3)

have contributed to the high rate of bolting observed at Samaru 13 weeks after transplanting. Jourbert and Strydom (1968) confirmed that bolting is basically an inherited characteristic that could be increased by low temperatures. However, bolting was not correlated to weed infestation and did not reduce bulb yield in onions at Samaru (Table 5).

(f) Number of plants at harvest: Various treatments did not influence the number of plants at harvest, which ranged between 93.6 and 99.1%.

3. Onions yields

The effects of herbicides on bulb yield of onions at Samaru are summarised in Table 6 and also illustrated in Fig. 6.

Pre-transplant herbicides, chlorthal-dimethyl, fluorodifen and oxadiazon, gave significantly higher bulb yields both at sampling, 13 weeks after transplanting, and at final harvest, 18 weeks after transplanting, than the post-transplant herbicide treatments (Table 6). The yields obtained with pre-transplant herbicides were comparable to those from the hoe-weeded and weed-free controls. This provided a clear indication of the effectiveness of these herbicides for selective control of weeds

Table 6. The effects of herbicide treatments on onion yield (t/ha) at Samaru, 1979-80 dry season.

Treatments		Fresh bulb + leaves	Air dry bulbs	Fresh bulbs + leaves	Air dry bulbs	Oven dry leaves
Herbicide	Rate Kg a.i./ha	----13 WAT---		--------18 WAT--------		
Pre-transplant						
Chlorthal-dimethyl	12.0	45.4	27.2	39.2	34.1	2.7
Fluorodifen	1.5	43.8	29.6	35.2	30.8	2.4
Fluorodifen	3.0	42.9	26.3	34.8	31.0	1.9
Oxadiazon	1.0	41.9	26.7	37.8	33.3	2.1
Oxadiazon	2.0	42.0	25.3	38.5	33.4	2.5
Post-transplant						
Chloroxuron	2.0	29.7	20.2	22.1	19.2	1.6
Chloroxuron	4.0	33.7	24.4	25.2	22.2	1.3
Chloroxuron	2.0 fb 2.0	33.5	20.4	24.8	21.4	1.5
Methazole	1.0	29.2	16.5	23.5	19.9	1.6
Methazole	2.0	33.4	25.2	29.0	25.3	2.0
Bentazone + linuron	1.2 + 0.4	34.8	19.6	24.4	20.2	1.6
Bentazone + linuron	1.2 + 0.8	32.2	20.3	26.4	21.9	1.6
Controls						
Hoe-weeded	-	34.6	20.4	39.3	32.8	3.4
Weed-free	-	38.9	24.6	39.0	33.4	3.1
Unweeded	-	30.9	16.7	19.6	16.2	1.5
LSD (.05)		4.0	7.2	7.5	8.4	0.86

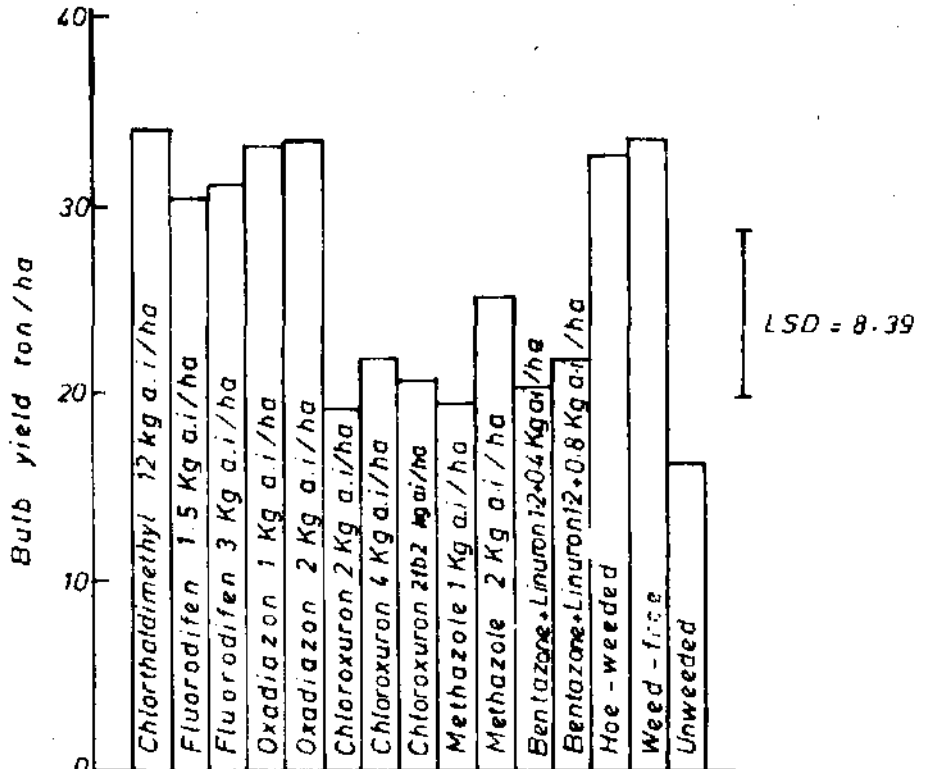


Fig.6 : Relative bulb yield of onions as affected by herbicide treatments during the 1979-80 dry season at Samaru

in onions. The results obtained in this trial were in confromity with those obtained by other investigators like; Green (1972), Noll (1975) and Selleck and Sanok (1978) on the use of chlorthal-dimethyl for selective weed control in onions. Leefe (1973), Sanok and Weber (1975), Randhawa (1977) and Sandhu and Randhawa (1978) earlier reported excellent weed control with increased onion yield in their studies with oxadiazon while Green (1972) and Zahran et al. (1971) reported fluorodifen to be a promising and effective herbicide for the control of weeds with no crop injury and increased onion yield. In addition, bulb yields obtained in the present study with these pre-transplant herbicides contained more marketable (larger) bulbs than that of the hoe-weeded control (Table 4). Fluorodifen at 1.5 kg/ha was as good as twice this rate. Although there was no apparent difference in yield at harvest between fluorodifen at 1.5 kg/ha and the hoe-weeded control, this herbicide at the above rate produced significantly higher bulb yield at sampling, 13 weeks after transplanting, than the hoe-weeded control (Table 6). There was also no difference in crop and bulb yields obtained with oxadiazon at 1.0 kg/ha and 2.0 kg/ha both during sampling and at the final harvest.

Weed infestation during crop growth depressed onion yield by 52% at Samaru. The bulb yield obtained with th hoe-weeded treatment was comparable to the weed-free treatment, indicating that five hoe-weedings were sufficient to get maximum yield and no gain could be obrained with further weed removal. By removing the soil around the bulbs, it wss observed that bulbs were fully formed eight weeks after transplanting in the field. This stage is usually followed by bulb enlargement indicating that the critical bulb formation stage had been passed (Plate 9).

Among the post-transplant herbicides, methazole at 2.0 kg/ha gave the highest crop and bulb yield both at sampling, 13 weeks after transplanting, and at final harvest, 18 weeks after transplanting. All the post-transplant herbicide treatments except methazole at 2.0 kg/ha gave final bulb yields which were significantly lower than the hoe-weeded control (Table 6). This yield reduction seems to have resulted from the poor weed control, particularly of grasses. Moreover, these herbicides did not seem to have enough residual activity to control subsequent weeds that emerged two weeks after spray. This observation is not in agreement with the long (up to 12 weeks) residual effect credited to methazole on mineral soils (Edwards, 1972). Earlier reports from



Plate 9. Bulb formation; bulbs were fully formed 8 weeks after transplanting showing that the critical bulb-formation stage had been passed. Samaru 1979-80 dry season.

Tasmania, Australia, indicated that cold weather reduced the effectiveness of methazole (Anon,, 1974b). This could have been due to low temperature effect at Samaru judging from the temperatures recorded during the growing season (Appendices C1 - C4 and Fig. 3). Unlike the findings of Mahadeva and Reesor (1973) where bentazone in combination with chlorthal-dimethyl effectively controlled weeds in onions, a combination of bentazone and linuron did not perform well in the present study and this could be due to poor effect of linuron on grasses.

In addition to the poor weed control, the post-transplant herbicides (chloroxuron, methazole and bentazone plus linuron) caused crop toxicity in the form of burnt tips, scorching and yellowing during the growing season. This initial set back coupled with weed competition must have contributed to the lower yields obtained (Plates 10 and 11). Green (1972) observed onion crop toxicity with chloroxuron but was of the opinion that his method of application and excessive quantity of irrigation water which increased the root up-take of the herbicide escalated the toxicity. In the present study root up-take by onion plants was reduced by spraying this herbicide post-transplant, two days after irrigation and still its toxicity effect on onions was conspicously manifested in



Plate 10. Poor weed control and toxicity effects of chloroxuron on onions at Samaru, 1979-80 dry season.



Plate 11. Top plot shows oxadiazon with healty plants and good weed control; bottom plot was treated with chloroxuron at Samaru, 1979-80 dry season.

the scorching of the leaves (Plate 10). Green's findings and that of the present study do not agree with those of Hartfield and Sweet (1975) who reported good onion tolerance of chloroxuron in New York, USA. Inspite of the poor weed control, the yields obtained with post-transplant methazole at 2.0 kg/ha were significantly higher than that of the unweeded control. This could be attributed to the initial suppressing effect of this herbicide on weeds. Nevertheless, the reduced yields observed with the post-transplant herbicides underscores the need for the early weed control in onions.

Significant differences in dry leaf weight were observed between the hoe-weeded and most of the pre-transplant herbicide treatments although no difference was observed in the bulb yields (Table 6). The onion plants in the hoe-weeded and weed-free treatments continued to give new flushes of leaves up to a few weeks before harvest, which might not have contributed to final bulb yield. Similar observations had been made by Magruder and Allard (1937), Thompson and Smith (1938) and Manuel and Velasco (1962) who reported that under short-day conditions that prevail in the tropics, foliage leaves continue to emerge indefinitely without bulb formation taking place.

Highly significantly negative correlations were observed (Table 5) between bulb yield at harvest and the weed cover score (r =- 0.72) at 13 weeks after transplanting and weed weight at harvest, 18 weeks after transplanting (r =- 0.66). Leaf production, crop vigour and bulb diameter were all positively and significantly correlated with bulb yield at harvest. Bolting was not correlated with the bulb yield at harvest at Samaru (Table 5).

B. Kadawa Experiment

Weed spectrum at Kadawa experimental site was dominated with broad-leaved weeds such as Amaranthus spinosus L., Acanthospenum hispidum L., Bidens pilosa L., Boerhavia diffusa L., Portulaca oleraceae L., Solanum nigrum L., Talinum triangulare (Jacq.) Willd. and a sedge: Cyperus tuberosus Rottb. A list of weeds present at the site is given in Appendix A. Volunteer millet from the previous season cropping at this site invaded the crop half way through the growing season.

The crop performance at Kadawa in general, was not as good as that at Samaru location. A number of factors, in addition to higher weed infestation and shift in weed species, influenced the poor weed control and consequently low harvests obtained at this location. The physico-chemical analysis of the experimental soil at Kadawa (Table 1), indicated that the soil had very low fertility with CEC of 6 and organic matter content of 0.6 percent. Volunteer millet arising from the previous season cropping invaded the experimental plots during the critical bulb formation stage when onions were most susceptible to weed infestation. Bidens pilosa, an obnoxious broad-leaved weed which was not found at Kadawa during the previous season, became a major weed in the experimental

plots, half way through the growing season.

Despite the low yields due to the above mentioned problems, the treatment effects were clearly shown with apparent differences. The results obrained at Kadawa are discussed below.

1. Effects on weeds

(a) Weed cover score: The scores were taken at 4 and 16 weeks after transplanting and are shown in Table 7. At the time of first score, the pre-transplant herbicides chlorthal-dimethyl, fluorodifen and oxadiazon carried significantly lower weed cover than the rest of the treatments including the controls. There was no difference observed between chlorthal-dimethyl at 12.0 kg/ha, fluorodifen at 3.0 kg/ha and oxadiazon at 1.0 kg/ha 4 weeks after transplanting. It was rather too early to judge the efficiency of the post-transplant herbicides since the application of these had not been completed when this first weed cover score was taken. Very few weeds emerged in the plots in the first three to four weeks after transplanting. This coupled with non-uniformity of weed growth delayed the application of the post-transplant herbicides. Since some of the weeds had overgrown by the time the post-transplant herbicide treatments

Table 7. Effects of various rates of herbicides on **weed growth in onions** at Kadawa during the dry season 1979-80.

Treatments Herbicides/	Rate Kg a.i./ha	Weed cover score 4 WAT t	4 WAT O	16 WAT t	16 WAT O	Weed weight (t/ha) 16 WAT O	19 WAT O
Pre-transplant							
Chlorthal-dimethyl	12.0	1.1	1.0	3.0	8.4	2.2	2.9
Fluorodifen	1.5	1.3	1.2	3.1	9.0	6.3	5.2
Fluorodifen	3.0	1.1	0.8	3.0	8.7	4.4	3.7
Oxadiazon	1.0	1.1	1.0	2.9	8.1	2.3	3.3
Oxadiazon	2.0	1.2	1.1	3.0	8.2	2.0	3.2
Post-transplant							
Chloroxuron	2.0	2.1	4.0	3.2	9.5	8.5	7.8
Chloroxuron	4.0	1.8	3.3	3.0	8.7	5.7	10.5
Chloroxuron	2.0 fb 2.0	2.3	5.0	3.2	9.7	8.7	7.4
Methazole	1.0	2.2	4.5	3.1	9.1	8.0	9.1
Bentazone + linuron	1.2 + 0.4	2.2	4.3	3.2	9.5	7.6	8.6
Bentazone + linuron	1.2 + 0.8	2.2	4.4	3.1	9.2	8.2	8.2
Controls							
Hoe-weeding	-	2.2	4.3	1.3	2.4	0.0	0.8
Weed-free	-	1.8	2.8	0.7	0.0	0.0	3.3
Unweeded	-	1.7	2.6	3.1	9.3	8.1	6.4
LSD (.05)		0.69		0.49		3.24	3.21

were applied, they proliferated and the weed cover in these treatments was even more than the unweeded control. As explained earlier for Samaru location, both hoe-weeded and weed-free treatments carried weeds when the first cover score was taken, 4 weeks after transplanting, at Kadawa.

By the time the second weed cover score was taken, at 16 weeks after transplanting, volunteer millets and weeds like Bidens pilosa L. and Acanthospermum hispidum L. had started to infest the plots and made it difficult to take the score precisely. Thus no differences were observed between unweeded control and the herbicide treatments. Weed weights gave a better measure of control under these conditions.

(b) Weed weights: Treatment effects on weeds collected both at sampling (16 weeks after transplanting) and at harvest (19 weeks after transplanting) are given in Table 7 and Fig. 7. At 16 weeks after transplanting, oxadiazon at 2.0 kg/ha proved to be the best among the herbicide treatments at this location. In addition, all the pre-transplant herbicides except fluorodifen produced significantly lower weed wiehgts than the post-transplant herbicides and the unweeded control at 16 weeks after transplanting.

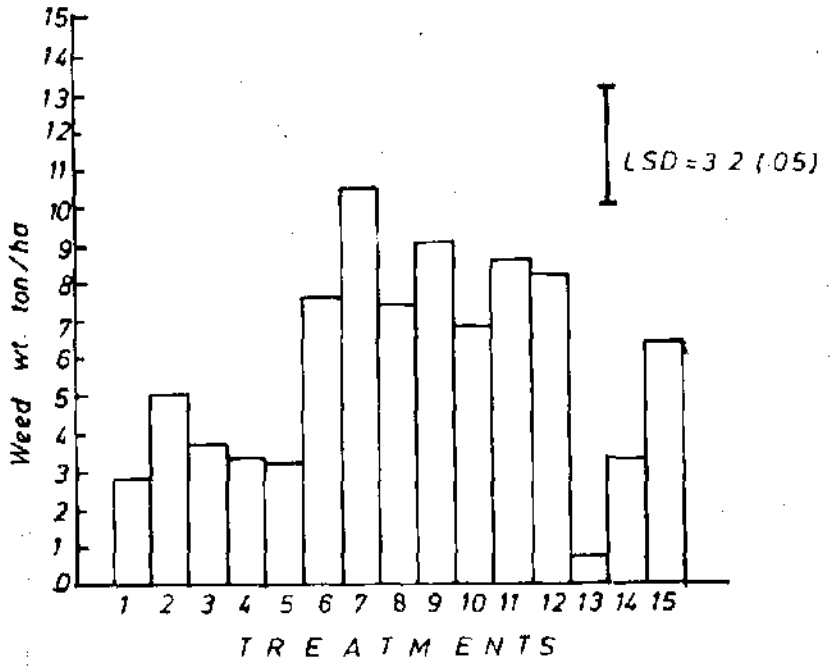


Fig. 7 : Effect of herbicides and their rates on dry wt. of weeds in onion at Kadawa 19 weeks after transplanting 1979-80 dry season

	TREATMENTS	Rate Kg a.i/ha
1	Chlorthaldimethyl	1
2	Fluorodifen	1.5
3	Fluorodifen	3
4	Oxadiazon	1
5	Oxadiazon	2
6	Chloroxuron	2
7	Chloroxuron	4
8	Chloroxuron	2fb2
9	Methazole	1
10	Methazole	2
11	Bentazone+Linuron	1·2 + 0·4
12	Bentazone+Linuron	1·2 + 0·8
13	Hoe-weeded	-
14	Weed-free	-
15	Unweeded	-

Even at the final harvest (19 weeks after transplanting), chlorthal-dimethyl at 12.0 kg/ha and exadiazon at 1.0 and 2.0 kg/ha were significantly superior to all the post-transplant herbicide treatments. All the post-transplant herbicides and the unweeded control gave lower total weed weights at final harvest than at sampling. This was a result of the uneven distribution of weeds and shift in weed population coupled with volunteer millet infestation.

2. Effect on yield attributes

The effects of various rates of herbicides on yield attributes measured at Kadawa are summarised in Table 8.

(a) Crop vigour score: This score was taken at 4 weeks after transplanting and no significant difference was observed among the treatments (Table 8). No signs of injury due to pre-transplant herbicides were observed also. The weeds had not established well during the first three weeks after transplanting and thus the crop growth was better and uniform during this weed-free period and therefore non-significant differences in the crop vigour were observed. However, the crop growth was retarded, in general, from middle January up to the third week in February, due to unfavourable weather condition (Appendix C.4 and Fig. 8).

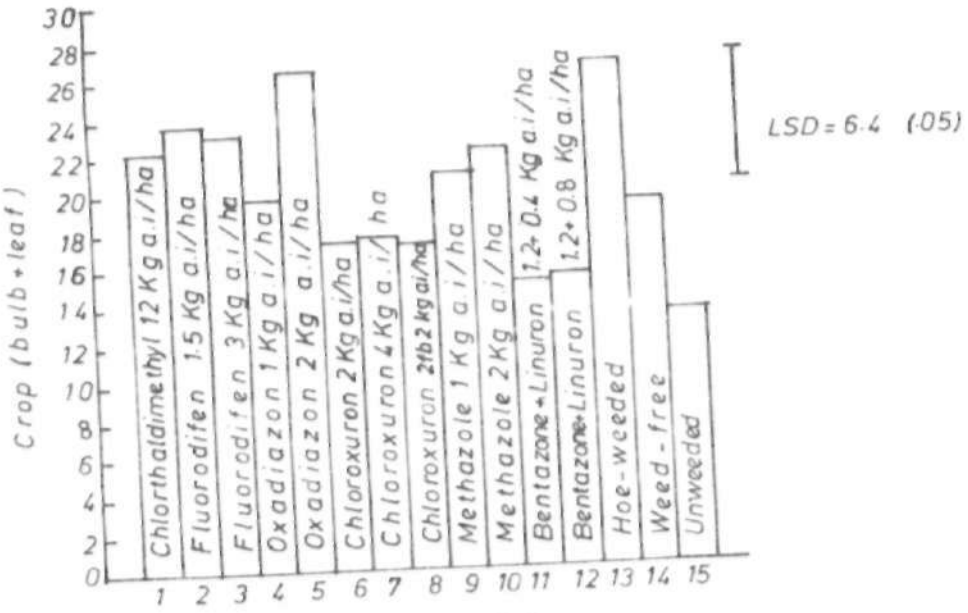


Fig. 9a: Crop yield of onion (Bulb + Leaf) 19 WAT at Kadawa, 1979-80 dry season

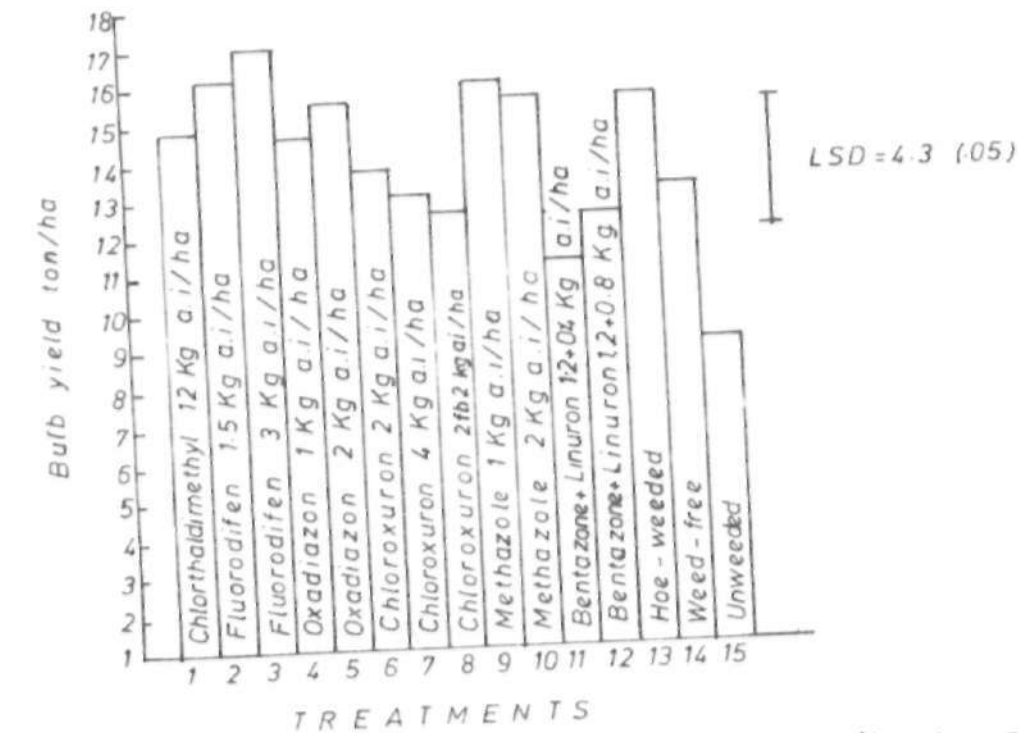


Fig. 9b: Onion bulb yield at harvest 19 weeks after transplanting at Kadawa, 1979-80 dry season

Table 8. The effects of various rates of herbicides on yield attributes of onion at Kadawa, during the dry season, 1979-80.

Treatments		Crop vigour score 4 WAT		No. of leaves/ plant 12 WAT	Plant height 12 WAT (cm)	Bolted plants 4 WAT (%)	Stand at harvest (%)
Herbicide	Rate Kg a.i./ha	t	O				
Pre-transplant							
Chlorthal-dimethyl	12.0	2.9	8.1	7.6	45.1	24.2	94.4
Fluorodifen	1.5	2.9	8.1	8.2	48.7	30.3	96.6
Fluorodifen	3.5	2.9	8.1	8.4	43.6	20.4	95.2
Oxadiazon	1.0	2.9	7.9	7.4	45.2	19.3	84.2
Oxadiazon	2.0	2.9	7.7	7.9	45.9	19.8	94.6
Post-transplant							
Chloroxuron	2.0	2.8	7.3	6.6	46.8	16.5	86.4
Chloroxuron	4.0	2.8	7.3	7.2	42.4	20.7	88.6
Chloroxuron	2.0 fb 2.0	2.9	7.9	6.8	50.9	22.3	84.2
Methazole	1.0	2.9	7.9	8.3	52.4	25.1	83.9
Methazole	2.0	2.9	8.2	8.7	43.7	30.8	90.5
Bentazone + linuron	1.2 + 0.4	2.6	6.5	7.0	45.1	16.8	73.7
Bentazone + linuron	1.2 + 0.8	2.7	7.0	7.9	38.1	19.3	78.4
Controls							
Hoe-weeded	-	2.9	7.9	8.3	42.9	17.4	91.6
Weed-free	-	2.6	6.3	6.6	36.1	15.2	82.0
Unweeded	-	2.7	6.6	5.8	44.1	18.7	83.1
LSD (.05)		NS		1.37	10.26	NS	NS

A second crop vigour score which was scheduled to be taken at 12 weeks after transplanting could not be taken due to the fact that the weeds and volunteer millet overtook the crop and made it difficult to do any accurate assessment of the crop vigour. Toxicity effects of the post-transplant herbicides especially chloroxuron and bentazone plus linuron were also observed in the form of burnt tips and yellowing of the onion plants resulting in poor crop vigour.

(b) *Leaf production:* The number of leaves produced at 12 weeks after transplanting varied significantly among the treatments (Table 8). Methazole, a post-transplant herbicide, and all the pre-transplant herbicides produced significantly more leaves than the weed-free control. Leaf production was found positively and highly correlated with bulb yield recorded 16 weeks after transplanting ($r = .495$), bulb yield at harvest 19 weeks after transplanting ($r = .487$) and bolting ($r = .330$) at Kadawa (Table 9).

(c) Plant height: Plant height measured 12 weeks after transplanting varied significantly among treatments with taller plants observed when the weed infestation was high (Table 8). This seemed to be the effect of competition

Table 9. Correlation analysis of some agronomic characters, yield of onions, weed cover score and weed weights at Kadawa, during the dry season, 1979-1980.

	Variables	'r' Values						
		2	3	4	5	6	7	8
1	Crop vigour score	...464**	.374**	.692**	.534**	.537**	.099	.121
2	Leaf production	.. ..	.495**	.487**	.131	.330**	-.059	-.106
3	Bulb yield (16 WAT) at sampling	.. .. ..		.462**	.123	.232*	-.008	-.086
4	Bulb yield at harvest (19 WAT)	.. ..			.480**	.300**	-.126	-.275
5	Plant height	.. ..				.345**	.205**	.105
6	Bolter production	.. ..					.165	.033
7	Weed cover score	.. ..						.442**
8	Weed weight(Total)							

** Significant at one per cent (P = .01)

* Significant at five per cent (P = .05)

for light between the tall grass and broad-leaved weeds on one hand and onion seedlings on the other.

(d) Number of bolted plants: No significant differences were observed 4 weeks after transplanting (Table 8) showing that this agronomic character was not affected by treatments. Later in the growing season more plants bolted on plot basis at Kadawa than at Samaru perhaps due to the lower temperature observed at Kadawa site.

(e) Stand at harvest: No significant differences were observed in the crop stand among the treatments at the time of harvest (Table 8). The stand in some of the treatments was lower, however, due to physical injury at the time of harvest which was unavoidable as a result of excessive weed growth which had completely masked the crop.

(f) Dry weight of leaves: There were no significant differences observed among the treatments. Fewer number of leaves and low leaf weight in the weed-free treatment could have resulted, among other things, from the early weed competition because the tiny weeds were not easy to pull out by hand as soon as they emerged. Hand-pulling did not result in effective removal of the weeds because the young seedlings of grass weeds snapped on hand-pulling leaving the rhizomes in the ground to regenerate and

compete with the crops for nutrients and moisture.

3. Effects on onion yields

The effects of various treatments on onion yields at Kadawa are given in Table 10 and illustrated in Figs. 9a and 9b. Bulb yields were generally low at Kadawa due to the reasons explained earlier. There was no difference in sample yield in all the treatments at 16 weeks after transplanting (Table 10).

Bulb yields obtained with all the pre-transplant herbicides were comparable to the hoe-weeded and were significantly higher than that of the unweeded check (Table 10). No significant differences were observed among the pre-transplant herbicides although fluorodifen at 3.0 kg/ha gave higher yield than the others. There were no significant differences observed in oven dry leaf weight also among the treatments. The fresh bulbs plus leaves showed similar trends except for oxadiazon at 1.0 kg/ha which gave significantly lower fresh bulb plus leaves than the hoe-weeded check.

The performance of post-transplant herbicides, particularly of methazole, on bulb yield of onions was better at Kadawa as compared with Samaru. The bulb yields from methazole treatment compared favourably with those of the

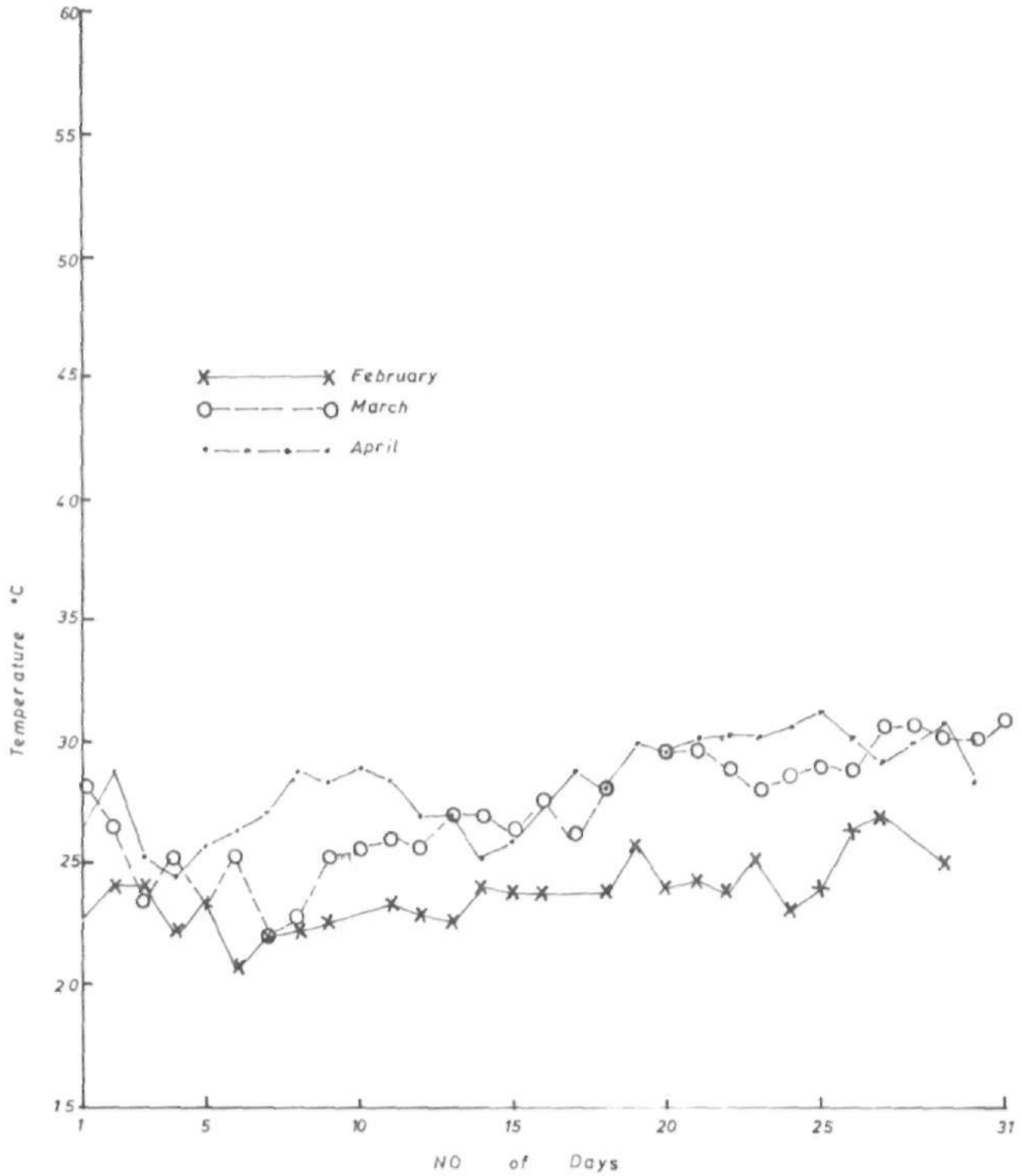


Fig.8 : Daily mean air temperature at Kadawa Irrigation Research Station (Feb. – April 1980)
(From Appendix C4)

Table 10. The effects of herbicide treatments on onion yield (t/ha) at Kadawa during 1979-80 dry season.

Treatments		Air dry bulb	Fresh bulbst leaves	Air dry bulbs	Oven dry leaves
Herbicide	Rate Kg a.i/ha	-16 WAT-	--at harvest----------		
Pre-transplant					
Chlorthal-dimethyl	12.0	10.0	22.2	14.9	1.7
Fluorodifen	1.5	13.8	23.8	16.2	4.5
Fluorodifen	3.0	14.7	23.0	17.0	1.3
Oxadiazon	1.0	14.4	19.8	14.7	1.3
Oxadiazon	2.0	14.7	26.4	15.5	1.0
Post-transplant					
Chloroxuron	2.0	9.2	17.4	13.8	0.9
Chloroxuron	4.0	13.2	17.6	13.0	0.9
Chloroxuron	2.0 fb 2.0	11.4	17.3	12.6	0.7
Methazole	1.0	13.2	20.9	16.0	1.3
Methazole	2.0	14.7	22.0	15.5	1.5
Bentazone + linuron	1.2 + 0.4	12.0	15.0	11.4	1.3
Bentazone + linuron	1.2 + 0.8	14.1	15.4	12.6	0.1
Controls					
Hoe-weeding	-	14.1	26.4	15.5	2.4
Weed-free	-	10.4	19.0	13.3	1.2
Unweeded	-	9.8	13.4	9.1	0.8
LSD (.05)		NS	6.14	4.3	NS

hoe-weeded control and pre-transplant herbicides (Table 10). The bulb yields from chloroxuron split application and bentazone plus linuron were significantly lower than that of fluorodifen at 3.0 kg/ha. This seems to have resulted from excessive weed growth in these treatments (Table 7). All the chloroxuron and bentazone plus linuron treatments had significantly lower fresh bulb plus leaves than the hoe-weeded check which further confirms their inefficiency in the control of weeds in onions in this study. The toxicity effect of the post-transplant herbicides especially chloroxuron on the crop was higher at Kadawa than that at Samaru.

Chapter V

SUMMARY AND CONCLUSIONS

Field experiments were conducted at Samaru and Kadawa during the 1979-80 dry season to study the effects of herbicides on the control of weeds in onions and compare them with the traditional hoe-weeding. The magnitude of weed infestation and yield losses due to weeds were also investigated.

Pre-transplant herbicides chlorthal-dimethyl at 12.0 kg/ha, fluorodifen at 1.5 and 3.0 kg/ha and oxadiazon at 1.0 and 2.0 kg/ha gave very good selective control of weeds in onions with bulb yields comparable to the hoe-weeded treatment at both locations. These herbicides kept onion plots almost weed-free for a period of 12 weeks after transplanting which covered the critical bulb formation stage. Yields obtained with these pre-transplant herbicides were significantly higher than those of methazole, chloroxuron and bentazone plus linuron applied post-transplant at Samaru location.

Post-transplant herbicides performed better at Kadawa than at Samaru. Methazole at 1.0 and 2.0 kg/ha was as good as the best pre-transplant herbicide at Kadawa. Generally

the post-transplant herbicides did not control the weeds satisfactorily, particularly grasses, in onions at Samaru location. Crop toxicity in the form of burnt tips and yellowing was observed with the post-transplant herbicides especially with chloroxuron. Higher rates of the post-transplant herbicides gave better results than their lower rates used especially at Samaru.

Weed infestation reduced bulb yield by 52% at Samaru and 46% at Kadawa. Weeds not only reduced bulb yield drastically but gave rise to split and twin bulb formation, reduced bulb size and increased number of rotten bulbs.

Crop performance and harvests were quite satisfactory at Samaru where bulb yield of up to 34.1 t/ha was obtained. The general crop performance and the bulb yield at Kadawa, however were quite low, as compared to those at Samaru. Factors likely to have contributed to the poor crop performance at Kadawa were; poor fertility, nature and magnitude of weed infestation and volunteer millet plants.

All the agronomic characters measured were influenced by treatment effects and showed positive correlations with the final bulb yield. Bolting was an exception at Samaru

where it did not show significant correlation with bulb yield.

Apart from providing early weed control which is required to achieve reasonable bulb yield of onion, pre-transplant herbicides present less problems as regards application and crop toxicity than the post-transplant herbicides. The reduced yields observed with the post-transplant herbicides under-scores the need for early weed control in onions.

Chemical weed control in onions appears to be more promising than the high labour demanding, costly and strenuous hoe-weeding method being used at present in Nigeria. Five hoe-weedings were enough to achieve maximum bulb yield in onions in this study and all the pre-transplant herbicides used were comparable to this. No obvious advantage in bulb yield was observed at both Samaru and Kadawa to justify the high cost of keeping onion fields competely weed-free throughout the growing season.

Higher rates of post-transplant herbicides are likely to control weeds better than the lower rates used in the present study, but the danger of crop toxicity is bound to be higher especially on the mineral soils of Samaru and

Kadawa which are generally low in organic matter content. Post-transplant herbicides could be used at normal rate as a follow-up spray to effective pre-transplant herbicides when the activities of the latter break down to provide onions with extended weed-free environment in the growing season.

From the studies, it is evident that satisfactory weed control could be achieved with good crop yield using chlorthal-dimethyl at 12.0 kg/ha, fluorodifen at 1.5 kg/ha or oxadiazon at 1.0 kg/ha. The herbicide chlorthal-dimethyl is not yet imported in Nigeria nor a price is quoted for this and thus comparative economics of herbicide could not be undertaken.

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* Original paper not seen.

Appendix A. Common (Trade) and Chemical names of herbicides mentioned in the thesis.

Common/ Trade name	Chemical name
Aziprotryne	2-azido-4-isopropylamino-6-methylthio-1,3, 5-triazine
Bentazone (Basagram)	3-isopropyl-2,1,3-benzothiadiazin-4-one 2, 2-dioxide
Chloroxuron (Tenoran)	N-4-(4-chlorophenoxy)phenyl-N,N-dimethyl-urea
Chlorthal-dimethyl (DCPA or Dacthal)	2,3,5,6-tetrachloroterephthalic acid dimethyl ester
Fluorodifen (Preforan)	4-nitrophenyl 2-nitro-4-trifluoromethyl phenyl ether
Linuron (Afalon)	N-(3,4-dichlorophenyl)-N-methoxy-N-methyl urea
Methazole (Paxilon)	2-(3,4-dichlorophenyl-1,2,4-methly-1,2,4-oxadiazolidine-3,5-dione
Oxadiazon (Ronstar)	3-(2,4-dichloro-5-isopropoxyphenyl)-5-t butyl-1,3,4-oxadiazolin-2-one
Propachlor (Ramrod)	a-chloro-N-isopropylacetanilide

Appendix B: Weed species at the experimental sites[1].

Weeds	Locations	
	Samaru	Kadawa
Broad-leaved		
Acanthospermum hispidum L.		**
Amaranthus spinosus L.	*	**
Amaranthus viridis L.	*	*
Bidens pilosa L.	-	**
Boer havia diffusa L.	*	**
Emilia sonchifolia (L.) DC.	*	*
Euphorbia hirta L.	**	*
Ipomoea purporea L.	-	*
Portuleca oleraceae L.	**	**
Sida acuta (Burm.) F.	-	*
Solanum nigrum L.	**	**
Talinum triangulare (Jacq.) Willd.	-	**
Tridax procunbens L.	*	*
Annual grasses		
Axonopus compressus (SW.) Beauv.	**	*
Brachiaria distichophylla (Trin.) Stapf.	*	-

[1]Symbols: ** dominant, *present, - absent.

Annual grasses (contd.)		
Chloris pilosa Schum.	**	-
Cynodon dactylon (L.) Pers.	*	*
Dactyloctenium aegyptium (L.) Beauv.	**	**
Digitaria horinzontalis Willd.	**	**
Eleusina indica L.	**	**
Rotboelia exaltata (L.) F.	-	*
Sedges		
Cyperus esculentus L.	*	*
Cyperus tuberosus L.	*	**

Appendix C. 1: Temperature, Relative Humidity and other meteorological information at Samaru (11° 11'N, 07°38'E; 685 m altitude) January 1980.

Days	Air Temp. (°C)			Relative Humidity (%)			Soil Temp. 5 cm (°C)			Pan Evaporation (MM)	Sunshine (hrs)
	Max	Min	Daily Mean	AM	PM	Daily Mean	AM	PM	Daily Mean		
1	27	12	19.5	21	21	21	21	27	24	9.9	9.1
2	28	11	19.5	20	16	18	21	27	24	10.2	9.9
3	29	12	20.5	17	15	16	21	28	24.5	11.7	9.4
4	30	13	21.5	16	14	15	21	28	24.5	8.6	9.8
5	29	13	21.0	11	17	14	21	28	24.5	12.2	9.2
6	29	13	21.0	8	15	11.5	22	28	25	10.2	6.6
7	29	13	21.0	19	14	16.5	21	28	24.5	8.6	9.6
8	30	13	21.5	15	11	13	22	28	25	10.2	9.8
9	29	15	22.0	14	14	14	21	27	14	9.7	8.8
10	31	14	22.5	13	16	14.5	20	28	24	6.1	8.0
11	31	13	22.0	15	17	16	20	28	24	8.6	9.4
12	31	13	22.0	17	16	16.6	22	28	25	8.1	9.8
13	33	12	22.5	14	31	22.5	21	29	25	8.6	9.5
14	33	13	23.0	11	13	12	22	28	25	8.6	10.4
15	35	12	23.5	16	15	15.5	22	29	25.5	6.6	9.8
16	36	14	25.0	18	18	18	23	30	26.5	8.1	10.2
17	35	13	24.0	24	11	17.5	24	30	27	9.1	9.9
18	36	16	26	36	30	33	23	29	26	8.6	7.8

Appendix C. 1 (contd.):

Days	Air Temp (°C)			Relative Humidity (%)			Soil Temp. 5 cm (°C)			Pan Evaporation (MM)	Sunshine (hrs)
	Max	Min	Daily Mean	AM	PM	Daily Mean	AM	PM	Daily Mean		
19	35	15	25	14	19	16.5	23	30	26.5	8.1	10.0
20	35	14	24.5	19	19	19	22	30	26	11.2	10.0
21	35	14	24	16	11	13.5	23	32	27.5	11.2	10.5
22	33	15	24	16	12	14	24	30	27	9.1	8.5
23	32	16	24	16	14	15	23	30	26.5	11.7	10.0
24	30	15	22.5	19	16	17.5	22	30	26	11.7	9.5
25	28	13	20.5	16	12	14	22	29	25	8.6	9.0
26	27	12	19.5	13	14	13.5	22	29	25.5	19.1	8.5
27	27	11	19	18	13	15.5	21	29	25	11.2	9.0
28	30	11	20.5	20	15	17.5	20	28	24	10.2	9.5
29	31	12	21.5	13	15	14	21	29	25	7.1	9.6
30	32	14	23	13	14	13.5	21	29	25	8.6	10.5
31	32	12	22	21	9	15	21	30	25.5	7.6	10.8

Appendix C. 2: Temperature, Relative Humidity and other meteorological information at Camaru (11°11'N, 07°38'E; 685 cm altitude) February 1980.

Days	Air Temp. (°C)			Relative Humidity (%)			Soil Temp. 5 cm (°C)			Pan Evaporation (MM)	Sunshine (hours)
	Max	Min	Daily Mean	AM	PM	Daily Mean	AM	PM	Daily Mean		
1	31	14	22.5	7	12	9.5	21	30	25.5	11.2	9.7
2	31	14	22.5	11	9	10	21	30	25.5	10.7	10.5
3	30	14	22	10	13	11.5	22	30	26	10.2	9.8
4	28	17	22.5	11	12	11.5	22	27	24.5	10.2	0.0
5	28	15	21.5	18	13	15.5	21	27	24	11.7	2.4
6	28	13	20.5	15	17	16	21	27	24.5	9.7	1.8
7	29	11	20	14	23	18.5	20	27	23.5	9.7	5.7
8	31	13	22	15		18.5	21	28	24.5	8.6	9.4
9	32	15	23.5	15	9	12	21	29	25	9.7	10.5
10	32	15	23.5	14	12	13	22	29	25.1	10.7	10.0
11	32	15	23.5	18	14	16	22	30	26	10.6	6.5
12	34	15	24.5	20	11	15.5	22	31	26.5	13.8	9.8
13	31	14	24	20	13	16.5	22	31	26.5	15.4	10.3
14	31	14	22.5	17	14	15.5	22	31	26.5	14.5	8.4
15	31	18	24.5	15	20	17.5	23	31	27	13.1	7.0
16	31	15	23	17	19	18	24	31	27.5	13.3	10.3

Appendix C. 2 (contd.):

Days	Air Temp. (°C)			Relative Humidity (%)			Soil Temp. 5 (°C)			Pan Evaporation (MM)	Sunshine (hours)
	Max	Min	Daily Mean	AM	PM	Daily Mean	AM	PM	Daily Mean		
17	31	15	23	14	26	20	24	30	27	13.2	3.6
18	33	18	25.5	14	11	12.5	24	31	27.5	15.2	6.6
19	34	16	25	15	17	16	25	31	28	13.7	10.6
20	33	17	25	12	13	12.5	24	32	28	12.9	9.8
21	35	17	26	16	14	15	24	32	28	14.2	10.3
22	36	17	26.5	10	9	9.5	25	33	29	14.6	10.0
23	37	20	28.5	6	7	6.5	25	33	29	19.0	10.2
24	33	20	26.5	8	7	7.5	25	31	28	15.9	9.8
25	34	21	27.5	9	15	12	32	28	11.9	6.3	6.3
26	36	17	26.5	7	13	10	24	33	28.5	12.5	5.7
27	26	18	22	17	15	16	26	34	30	12.0	9.2
28	35	16	25.5	12	13	12.5	25	34	29.5	12.2	8.6
29	33	18	25.5	12	12	12	24	33	28.5	15.0	6.4

Appendix C. 3: Temperature, Relative Humidity and other meteorological information at Samaru ($11^{o}11'N$, $07^{o}38'E$; 685 cm altitude) March 1980.

	Air Temp. (^{o}C)			Relative Humidity (%)			Soil Temp. 5 cm (^{o}C)				
Days	MAx	Min	Daily Mean	AM	PM	Daily Mean	AM	PM	Daily Mean	Pan Evaporation (MM)	Sunshine (hours)
1	32	18	25	3	9	8.5	25	33	29	10.7	8.0
2	31	18	24.5	19	11	15	25	32	28.5	-	5.8
3	32	15	23.5	13	7	10	25	33	29	-	10.0
4	34	17	25.5	11	7	9	25	33	29	-	8.9
5	34	16	25	11	7	9	25	33	29	-	10.5
6	36	15	25.5	16	11	13.5	26	24	30	-	10.1
7	34	20	27	15	16	27	25	31	31	9-7	8.8
8	34	20	27	10	9	9.5	27	24	30.5	8.6	8.2
9	35	20	27.5	10	10	10	26	35	30.5	9.7	9.5
10	36	19	27.5	11	11	11	26	35	30.1	9.7	9.5
11	36	18	27	9	11	10	27	35	31	8.6	8.3
12	35	18	26.5	11	13	12	27	34	30.5	9.7	6.6
13	36	15	25.5	27	11	19	27	35	31	10.2	10.3
14	36	15	25.5	13	12	12.5	26.	35	30.5	10.7	10.6
15	36	15	25.5	8	12	10	26	37	31.5	12.7	10.6
16	36	15	26.5	9	12	10.5	26	36	31.`	12.2	10.2
17	37	20	28.5	7	7	7	27	35	31	12.7	9.5

Appendix C. 3 (contd.):

Days	Air Temp. (°C) Max	Min	Daily Mean	Relative Humidity (%) AM	PM	Daily Mean	Soil Temp. 5 cm (°C) AM	PM	Daily Mean	Pan Evaporation (MM)	Sunshine (hours)
18	37	21	29.5	6	7	6.5	28	36	32	10.7	9.5
19	38	21	29.5	13	10	11.5	30	36	33	33.5	10.7
20	38	23	30.5	37	17	27	30	37	33.5	10.7	7.0
21	40	23	26.5	39	14	26.5	31	37	34	11.2	9.4
22	39	24	31.5	56	17	36.5	31	37	34	9.7	9.0
23	39	21	30	53	21	37	30	36	33	10.7	8.8
24	38	21	29.5	53	23	38	30	38	34	9.1	9.0
25	35	23	29	59	30	44.5	30	37	33.5	4.6	3.6
26	36	23	29.5	59	33	46	29	37	33	13.7	6.4
27	34	23	28.5	11	11	11	29	37	33	11.7	9.2
28	33	20	26.5	16	11	13.5	27	36	31.5	15.2	5.0
29	33	16	24.5	17	6	11.5	27	35	31	11.7	5.2
30	34	17	25.5	14	11	12.5	27	36	31.5	12.2	9.8
31	36	17	26.5	15	13	14	27	36	31.5	12.2	9.2

Appendix C. 4: Kadawa Irrigation Research Station ($11^{o}.39'N$; $08^{o}.02'$)

Metereological Records of Temperature. February - April, 1980.

	February			March			April		
Days	Max	Min	Daily Mean	Max	Min	Daily Mean	Max	Min	Daily Mean
1	33.3	12.2	22.8	37.1	19.6	28.4	35.7	17.7	26.7
2	34.1	12.4	23.3	35.1	18.3	26.7	36.7	20.6	28.7
3	33	13	23	30.3	17.1	23.7	33.3	17.2	25.3
4	31.7	12.2	22	31.6	18.8	25.2	32.7	16.8	24.8
5	32.2	15.0	23.6	31.1	16.1	23.6	34.7	17.1	25.9
6	30.9	10.6	20.8	34.2	19.	26.1	35.3	17.4	26.4
7	31.2	13.3	22.3	29.4	14.8	22.1	36.0	18.2	27.1
8	31.7	12.3	22.	31.1	14.3	22.7	38.9	18.9	28.9
9	31.0	13.9	22.5	31.4	19.0	25.2	40.1	17.2	28.7
10	32.7	13.8	23.3	35.1	16.0	25.6	39.8	18.3	29.1
11	31.7	15.0	23.4	36.6	15.5	26.1	37.8	19.5	28.7
12	32.8	12.9	22.9	34.3	17.5	25.9	37.1	17.2	27.2
13	33.3	12.2	22.8	35.6	18.3	27.0	36.4	18.0	27.2
14	32.9	15.1	24.0	36.9	17.2	27.1	34.4	16.1	25.3
15	31.7	15.6	23.7	37.4	15.2	26.3	35.7	16.2	26.0
16	33.5	13.9	23.7	37.8	17.6	27.7	38.3	16.7	27.5

Appendix C. 4 (contd.):

Days	February			March			April		
	Max	Min	Daily Mean	Max	Min	Daily Mean	Max	Min	Daily Mean
17	32.3	15.3	23.8	36.7	15.3	26.0	38.3	19.4	28.9
18	32.0	15.7	23.9	37.8	18.3	28.1	40.0	16.1	28.1
19	34.4	16.9	25.7	39.7	18.0	57.7	39.6	18.9	29.3
20	35.0	13.6	24.3	40.2	18.7	29.5	38.8	19.3	29.1
21	35.7	13.9	24.8	41.3	18.4	29.9	38.4	21.6	30.0
22	34.8	13.0	23.9	40.3	17.7	29.0	38.3	22.2	30.3
23	36.1	14.7	25.4	37.8	19.3	28.6	38.9	21.7	30.3
24	32.1	15.4	23.8	38.5	18.4	28.5	39.4	21.9	30.7
25	31.2	17.3	24.3	37.0	19.0	29	40.0	22.3	31.2
26	36.2	16.5	26.4	38.9	18.6	28.8	40.7	19.4	30.1
27	36.7	17.9	27.3	38.1	23.3	30.7	38.9	19.4	29.2
28	36.7	15.6	26.2	38.2	23.2	30.7	40.7	19.4	30.1
29	34.3	16.0	25.2	40.1	20.6	30.4	38.9	22.8	30.9
30	-	-	-	37.7	22.8	30.3	32.8	23.9	28.4
31	-	-	-	39.8	22.6	31.2	-	-	-

Appendix D. 1: Analysis of Variance for Crop Vigour, Leaf Count, Plant Height Bulb Diameter and Number of Bolters from herbicide treatments on onion at Samaru, during 1979-80 dry season.

Source of Variance	D.F.	Mean Square				
		Crop Vigour	Leaf Count	Plant Height	Bulb Diameter	Number of Bolters
Treatment	14	0.158**	2.442**	40.939	.699**	257.76
Block	3	0.320**	2.040	16.394	0.950**	1491.46**
Error	41	0.031	0.915	30.67	0.196	288.92

** Significant at 1 per cent level.

Appendix D. 2: Analysis of Variance on Bulb yield Fresh bulb + Leaf yield resulting from herbicide treatments on onion at Samaru, dry season 1979-80.

Source of Variance	D.F.	Mean Square	
		Airdry Bulb	Fresh Bulb + Leaf
Treatment	14	167.805**	211.261**
Block	3	97.980*	149.119**
Error	42	27.854	34.529

* Significant at 5 per cent level.

** Significant at 1 per cent level.

Appendix D. 3: Analysis of variance for weed cover, and dry weed weight resulting from herbicide application on onion at Samaru, during the dry season 1979-80.

Source of Variance	D.F.	Mean Square: Weed cover 4 weeks after transplanting.	Weed cover 12 weeks after transplanting.	Dry weed weight 13 weeks after transplanting	Dry weed weight at harvest
Treatments	14	1.943**	2.987**	1.847**	42.136**
Block	3	0.899**	0.163**	0.235	21.835**
Error	42	0.099	0.040	0.120	5.820

** Significant at 1 per cent level.

Appendix D. 4: Analysis of Variance for Bulb yield, Fresh bulb + leaf yield resulting from herbicide treatments on onion at Kadawa 1979-80 dry season.

Source of Variance	D.F.	Bulb yield 16 weeks after transplanting.	Fresh bulb + leaves, 16 weeks after transplanting.	Bulb yield at harvest	Fresh bulb + leaves 16 weeks after transplanting.
Treatment	14	14.882	1.174	20.490**	51.450**
Block	3	15.016	1.781	79.459**	142.338**
Error	42	10.892	0.8	9.122	18.479

Appendix D. 5: Analysis of variance for dry weed weights resulting from herbicide treatments on onion at Kadawa during the dry season, 1979-80.

Source of Variance	D,F.	Mean Square	
		Weed weight 16 WAT	Weed weight at harvest
Treatment	14	2.784**	31.977**
Block	3	7.703**	.930
Error	42	18.479	5.055

Appendix D. 6: Analysis of variance for crop vigour score leaf count, plant height, and bumber of bolters from herbicides and their rates on onion at Kadawa during the dry season, 1979-80.

Sourcea of Variance	D.F.	Mean Square: Crop vigour	Leaf count	Plant height	No. of bolters
Treatment	14	0.055	2.717**	71.396	72.988
Block	3	0.186**	0.404	228.270**	118.511
Error	42	0.041	0.919	51.667	47.071