CHEMICAL WEED CONTROL IN GARLIC

(*Allium sativum L.*)

By

AMEL BAHRELDIN MOHAMED

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Supervisor: Dr. SALAH ELTOM ELAMIN

Associate professor

Department of Crop Protection

Faculty of Agriculture

University of Khartoum

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DEDICATION

TO WHOM THROUGH THEM I FEEL LIFE

TO MY FAMILY…

WITH LOVE

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ABSTRACT

Activity and selectivity of two pre-emergence herbicides for the control of annual weeds in garlic crop (*Allium sativum* L.*)* were evaluated during winter season of 1999/2000 and 2000/2001 in The Experimental Research Farm of The Faculty of Agriculture, University of Khartoum at Shambat, Sudan. The herbicides used were Stomp (pendimethalin) at 2.1 and 4.2 Kg.ai/ha, Goal (oxyfluorfen) at o.25 and 0.5 Kg.ai/ha, mixture between Stomp and Goal (Stomp at 2.1 Kg.ai/ha with Goal at 0.25 Kg.ai/ha and Stomp at 4.2 Kg.ai/ha with Goal at 0.5 Kg.ai/ha), and mixture between Stomp and Goal (Stomp at 2.1 Kg.ai/ha with Goal at 0.25 Kg.ai/ha followed by hand weeding and Stomp at 4.2 Kg.ai/ha with Goal at 0.5 Kg.ai/ha followed by hand weeding.

All herbicides treatments gave selective control of most annual grass and broad-leaved weeds and significantly increased garlic yield over the weedy check. However, all herbicides treatments reduced weed dry weight compared to weedy check. The increase in yield resulting from those treatments varied from 51 to 221%. Only mixture between Stomp and Goal followed by hand-weeding gave yield comparable with that obtained from weed free check. The increase in garlic yield due to the application of the herbicides was mainly due to an increase in garlic bulb weight and increase in number of cloves per bulb.

The herbicide Goal reduced the growth of garlic, because of some tolerant broad-leaved weeds, but the final yield significantly was better than weedy check.

ملخص الا طروحه

تم تقيم فعالية واختيارية اثنين من مبيدات قبل الأنبات لمكافحة الحشائش الحولية فى محصول الثوم خلال موسمى الشتاء لعام 99\2000و2000\2001 في مزرعة الأبحاث التجريبية بكلية الزراعة جامعة الخرطوم-شمبات -السودان المبيدات التي تم أستخدامها: استومب بتركيز 2.1 و 4.2 كيلوجرام مادة فعالة للهكتار، مبيد قول بتركيز 0.25و 0.5 كيلوجرام مادة فعالة للهكتار، خليط بين استومب و قول (أستومب بتركيز 2.1 كيلوجرام مادة فعالة و القول 0.25كيلوجرام مادة فعالة للهكتاروأستومب بتركيز4.2 كيلوجرام مادة فعالة و القول0.5 كيلوجرام مادة فعالة للهكتار) و خليط بين استومب و قول (أستومب بتركيز 2.1 كيلوجرام مادة فعالة و قول 0.25كيلوجرام مادة فعالة للهكتاروأستومب بتركيز4.2 كيلوجرام مادة فعالة و القول0.5 كيلوجرام مادة فعالة للهكتار) مصحوبا بعزيق يدوى.

كل معاملات المبيدات أعطت مكافحة أختيارية لمعظم الحشائش الحولية عريضة الاوراق وضيقة الاوراق، وأدت الىتقليل الوزن الجاف للحشائش مقارنة بالشاهد الغير معشب، ايضاكل معاملات المبيدات ادت الى زيادة معنوية في انتاج الثوم مقارنة بالشاهد الغير معشب والزيادة فى الانتاجية نتيجة تلك المعاملات تراوحت بين % 51 و

221 فقط الخليط بين الأستومب والقول مصحوبا بالعزيق اليدوي أعطي نتيجة مقاربة للشاهد المعشب الزيادة في أنتاجية الثوم نتيجة لأستخدام هذه المبيدات كانت نتيجة لزيادة وزن البصلة وعدد الفصوص في البصلة. مبيد قول أدى الي تقليل النمو الخضري لنبات الثوم نتيجة لوجود بعض الحشائش عريضة الاوراق المقاومة لهدا المبيد لكن اجمالي الانتاجية كان ذو فرق معنوي مقارنة بالشاهد غير المعشب.

CHAPTER ONE

INTRODUCTION

Garlic (*Allium sativum* L.) a member of the family Alliaceae belongs to the genus Allium that comprises of more than 600 different species found throughout the world (Saleh, 1997).

Garlic is hard perennial plant native of southern Europe, it was known to the ancients and is said to have been disliked by Romans on account of the strong odor but was fed to their laborers and soldiers. Garlic also used in England as early as the first half of the sixteenth century (William and Homer, 1957).

World production of garlic ranks second to onions in importance among the Allium species. Garlic is grown in many countries, though at percent China, Egypt, India, Spain, South Korea, and Turkey are the principal producers (Anon, 1985).

Garlic is widely used for both its culinary and medicinal attributes (Bill *et al*., 1999). Fresh garlic is widely used in cooking, in some countries, particularly in Asia, the leaves of young nonbulbing plants and also freshly emerged young flower stalks are used as food (Brewster and Rabinowitch, 1990). Arange of alternative processed garlic products has been developed to meet the particular needs of individual market sectors, by forming raw material for a variety of food manufacturing processes

Dehydration, freezing, canning, and pickling (Brewster and Rabinowitch, 1990). Farrell (1985) describes dehydrated garlic as being available in six forms, powedered, minced,coarse, granulated, chopped, and diced.

Therapeutic values, and many folk-medicinal uses of garlic have developed in the past two decades, and there have been a number of scientific reports supporting its therapeutic uses (Brewster and Rabinowitch, 1990). Garlic has been described as a hot stimulant, carminative, antirheumatic, alterative, powerful antiseptic and a vermifuge for expelling roundworms (Nadkarni, 1957).

Lau *et.al* (1983) reported that garlic has long been recommended for cure of a number of ailments wounds, foul ulcers, pneumonia, bronchitis, atopic dyspepsia, and gastrointestinal disorders. Antibacterial, antifungal, antitumor, hypoglycemic, hypolipidemic, antiatherosclerotic, fibrinolytic,

and antiplatelet-agregation effects of garlic have been reported (Brewster and Rabinowitch, 1990).

In Sudan, garlic is grown during winter in the Northern State and in high altitude parts of western states (Abdalla, 1998). Dongola and Berber are the two main local cultivares grown in northern states. Aline introduced from China is recently released as a new cultivar (Abdel karem, 1996).

Garlic quality and yield per unit area in Sudan is very low compared to other producing countries. The yield per hectare in Sudan is approximately 2 tonnes/ hectare, while it is 3.6 tonnes/ hectare, in Turkey, 13.4 tonnes/ hectare in Egypt, 13.9 tonnes/hectare in United State of America, and 28 tonnes/hectare in Haiti (Abdel karem, 1996). Mohamed and Nourai (1997) realized that the major contraint for the production of garlic in Sudan is weeds, and yield loss ranged from 22 to 26%.

Garlic is slow growing, shallow-rooted crop that can suffer severe yield losses from weed competition. Their narrow, upright leaves do not compete well with weeds. In addition, their long growing season allows for successive flushes of weeds (Fischer *et al*., 2000). So to eliminate the early competition of weeds herbicides can be of great potential value (Mohamed and Nourai, 1997).

This research work was therefore, conducted to evaluate the selectivety and activity of the herbicides Goal (oxyfluorfen) and Stomp (pendimethalin) in controlling weeds in garlic.

CHAPTER TWO

LITERATURE REVIEW

2.1. Weeds:

Plants are considered weeds when they interfere with the utilization of land and water resources or otherwise adversely intrude upon human welfare, this mean that weeds are growing where other plants are supposed to grow or where no plants should be (Anon, 1986).

2.2. Harmful effects of weeds:

One of the most easily observable effects of weeds is that they decrease crop yields. This occurs mainly because the weeds compete with the crop plants for water, mineral nutrients and light. The competition for water and mineral nutrients is most severe and crops yields are most depressed when either of these factors is in short supply (Onwueme and Sinha, 19991). In some cases, weeds compete with crop plants, not just passively by drawing from the same pool of resources, but actively by producing substances that inhibit the growth and development of the crop plant, this is called allelopathic effect. Another form of aggressive competition occurs when the weed plants are actually parasitic on the crop plant (Onwueme and Sinha, 1991). Weed can also reduce yields indirectly by serving as reservoirs for various diseases and pests of crop plans. This factor is particularly critical in carry-over of disease organisms and pests from one season to the next (Onwueme and Sinha, 1991). Weeds in pastures can be nuisance, wool can be contaminated by the seeds of many weed species, the presence of burr and vegetable matter leads to a down grading of the fleece; also when animals eat wild garlic for example their milk and meat become tainted. This subsequently lowers the value of these products, even making them unsaleable (Elliott, 1999) the same author mentioned that certain weeds can cause injury to livestock, and some plants are poisonous to livestock. Other farming situations in which weeds cause problems include the clogging of canals and irrigation channels (Onwueme and Sinha, 1991), also some weeds make cultivation difficult by becoming entangled in machinery and preventing efficient harvesting (Elliott, 1999). Some weeds increasing fire hazards particularly when dry out (Elliott, 1999). Some species of weeds are very good competitors and shade out other plants. After the death of these weeds they leave the ground bare and prone to erosion (Elliott, 1999). Williams and Richard (2000) mentioned that more than 700 weeds plants are known to cause illness in humans. Elliott (1999) said that humans could be allergic to different types of weeds. Plants that you simply don't like or want can

be regarded as weeds. They may be interrupting a view, crowding bush land or other desirable species, have an offensive odor or be generally causing problems where they exit.

In term of economics, weeds add considerably to the cost of crop production. It is not just that they consume the water and nutrients that are provided for; farmer also has to spend an appreciable percentage of this annual budget on various weed control measures (Onwueme and Sinha, 1991). The worldwide sales of herbicides in 1980 amounted to 4.7 billion dollars (compared with $ 3.9 billions for insecticides, $ 2.5 billions for fungicides and $ 0.7 billion for growth regulators and others), thus in the course of little more than 40 years weed control has grown from practically nothing to a multi billion dollar business (Fletcher, 1983).

2.3. Losses in different crops due to weeds:

Losses in crop yield due to weeds are difficult to estimate, because it is almost impossible, without creating an artificial environment to separate their effects from those caused by insects, disease, soil and atmospheric conditions. Nevertheless it appears to be accepted that worldwide some 10% loss of agricultural production can be attributed to the competitive effect of those plants (Fletcher, 1983). Worldwide, in cereals alone this represents a loss of more than 155.5 billion tons. There are of course considerable variations between different countries, between different crops even between the same crops in different situations (Broadbent, 1978). Worldwide there is a 10.6% loss in rice, 13% loss in maize, 9.8% loss in wheat, 15.1% loss in sugar cane and 5.8% loss in cotton (Anon, 1983). In Bangladesh crops losses caused by weeds competition were estimated by Karim *et al.* (1998) and they found that production losses of 33.16 % in food crops, 41.26 % in cereals, 31.88 % in pulses, 40.82 % in oilseeds, 34.23 % in fiber crops and 40.28 % in rice were caused by weeds. In Sudan 18 to 83% yield losses were reported in horticultural crops due to

weed competition (Ishag, 1979). Koch *et al*., (1982) mentioned that weed densities reduced yield of seed cotton and groundnut by 74 and 73%, respectively and grain yield of sorghum by 47% in kenana area of Sudan Unrestricted weed growth reduced grain yield of chickpea and lentil by 81 and 63% (Al- Thababi *et al.,* 1994). According to Fageiry (1987) full season competition of weeds reduced seed yields of soybean by 78-100%. Babiker and Ahmed (1986) found that weed growth reduced yield of transplanted onion by 26-48%. Mohamed et al. (1997) found that the presence of weeds throughout the lentil-growing season resulted in 84 % loss. Mohamed (1992) reported that 70 % reduction in chickpea yield due to weeds infestation. Yield reduction (98 %) in onion due to weeds infestation in the Gezira Research station was reported by (Babiker et al., 1980). Braun *et al.* (1991) reported that losses due to weed competition in onion, cucumbers and egg-plants were 45-73%, 46–100% and 31–99% respectively. Mohamed and Mohamed (1992) reported that losses due to unrestricted weed growth in faba bean were 70%. Idris (2000) reported that unrestricted weed growth reduced grain yield of common bean by 33–51%.

2.4. Weed competition and yield losses in garlic (*Allium sativum* L.):

Several growth factors for example light, Co2 oxygen, water, and mineral nutrients are required for the development of plants. When any or all of the above essential elements are in short supply to a population of plants, competition occurs. The stronger competitor, weed or crop, inhibits the growth of its neighboring plant (Brewster and Rabinowitch, 1990).

Garlic in its early stages of development has both a slow growth rate and thin foliage. Therefore, this crop is considerably weaker competitor than most crops (Brewster and Rabinowitch, 1990). Weed competition in garlic at the early stage of growth results in severe yield losses. Weed competition adversely affects both total yield and the marketable share of the yield, namely the percentage of large or medium sized bulbs (Brewster and Rabinowitch, 1990).

In garlic cv. California late unweeded plots for 60, 90, 120 and 230 days after planting resulted in yield reduction of 11.8, 31.8, 43.2 and 52.7% respectively (Agamalian and Kurtz, 1989). In Sudan Mohamed and Nourai (1997) found that 22 to 26 % yield reduction due to weeds.

2.5. Methods of weed control:

Weeds are not, and probably never have been, of course allowed to grow undisturbed. From the earliest times farmers recognized their harmful effects and attempted to eliminate them (Fletcher, 1983). The primary goal of weed control program is to reduce as much as possible the weed stand, with minimal crop injury (Roberts, 1973).

There are several methods in which weeds can be controlled these methods are eradication, physical, cultural, biological, chemical, prevention, and integrated (Vernon, 2000; Anon, 1986; and Onwueme and Sinha, 1991).

2.5.1. Eradication:

Eradication is the elimination of all weed plants and plant parts from an area. This is not practical if the weed is well established or if many of its seeds are in the soil. It is feasible if a species has just invaded a field or is found only sporadically throughout the field (David, 1996). Cutting, pulling, or using a wiper or spot treatment to eliminate a few plants is much easier than trying to control weeds once they have become established. Periodic checking of your field for new weeds and eliminating them early can prevent serious weed problems (David, 1996).

2.5.2. Physical methods:

The common physical methods of weed control (manual or mechanical) are:

2.5.2.1 Hand pulling:

This is one of the simplest and most ancient methods of weed control, practiced today in certain situations such as in the home garden. It is particularly useful for removing weeds that are very close to the crop stand and where a minimum amount of soil

disturbance is desired. It is also used where the weed species to be removed occurs in relatively isolated stand (Onwueme and Sinha, 1991).

2.5.2.2. Hoeing:

Weeds can be destroyed readily while they are still small by hand hoeing, either by cutting off their tops or by stirring the surface soil so as to expose the seedling to the drying action of the sun (Walter, 1936). Hoeing is particularly more effective on annuals and biennials as weed growth can be completely destroyed. In case of perennials, it destroys the top growth with little effect on underground plant parts resulting in regrowth. However, it can be more effective on creeping perennials that have shallow root system like *Convolvulus arvensis* (Rao, 1983)

2.5.2.3. Machine tillage:

Tillage is done with implements drawn by animals or machines (tractors, tillers, ect.) (Rao, 1983). One of the more technologically advanced methods of weed control is the use of the plough, the harrow or the cultivator. The plough and harrow are most often used to control weeds before the crop is planted and between rows of the growing crop (Onuwueme and Sinha, 1991). Tillage removes weeds from the soil, resulting in their death. It may weaken weeds through injury or root and stem pruning, reducing their competitiveness or regenerative capacity.

However, tillage turnover and exposure weeds seeds to sunlight that can be destroyed effectively later. In case of perennials, both top and underground growth is injured or destroyed by tillage (Rao, 1983).

2.5.2.4. Burial:

In this method all the growing points of weed plant can be buried. This methods is most effective on annual weeds and usually less effective on perennial weeds which have underground stems and roots and are capable of regrowth from these underground storage organs (Vernon,2000).

2.5.2.5. Mowing:

Mowing is one of mechanical control, its main purpose is to prevent the weeds from producing seeds and for this reason, it has to be done fairy frequently (Vernon, 2000; Onwueme and Sinha, 1991). Mowing is effective on tall growing annual weeds, and not as effective on short growing plants or perennials (Vernon, 2000).

2.5.2.6. Mulching:

Mulching is a layer of non-living material placed over the surface of the soil. Mulch serves physically to smother the weeds and to cut them off from direct sunlight. In order to achieve a smothering effect, the mulch has to be relatively resistant to weed plant penetration. Where grass or other crop residue is used as mulch, it has to be in a relatively thick layer. Mulches consisting of a continuous layer of paper or opaque plastic are usually very effective for weed control (Onwueme and Sinha, 1991).

2.5.2.7. Burning:

Burning can be used to control weeds by killing the mature weed population and stimulating soil stored weed seeds to germinate so that they can be controlled while in the more susceptible seedling stage (Elliott, 1999).

2.5.2.8. Flooding:

This is also an effective method of weed control, although its use is mostly limited to rice, which able to grow under flooded conditions. Flooding kills weeds by reducing oxygen availability for weed growth (Rao, 1983).

2.5.3. Cultural methods:

These include any husbandry or management practices that enhance a crop's ability to compete with weeds. Cultural control is basically the art of managing vegetation (Anon, 1986).

2.5.3.1. Crop interference:

Crop interference may include both competition and allelopathy.

2.5.3.1.1. Crop competition:

Crop competition is usually one of the cheapest and best methods of weed control; however, it is often one of the most

overlooked methods. If crop has been grown under ideal conditions will have the competitive advantage and there are some factors have an influence on the competitive advantage of the crop such as planting date, row spacing, seeding rate, planting depth, soil moisture, soil fertility, and soil pH (Tredaway and Colvin, 2000).

2.5.3.1.2. Allelopathy:

Allelopathy is the ability of one plant to interfere with the growth of anther by the production of root exudates (Oudhia, 2002) .The Allelopathic potential in growing rice was first found in a seed-increasing plot at Arkansas Rice Research Institute (Dilay *et al*, 1991). However the African rice Javanica type *O. sativa, O. glabenima,* and wild rices have been suggested as possible sources of allelopathic activity (David, 1996).The utilization of allelopathy have considerable potential for low input weed management regimes (David, 1996).

2.5.3.2. Crop rotation:

If the same crop is planted in the field year after another there usually will be some weed or weeds which are tolerant and

favored by the cultural practices and herbicides used on that crop (Vernon, 2000). By rotating to other crop many of the cultural practices and herbicide programs are changed. This often will reduce the population of specific weeds which were tolerant in the previous crop (Vernon, 2000).

2.5.3.3. Inter-cropping:

William, 2002 reported that Combine broadleaf and taller, and narrow-leaf crops (corn or beans crops with pumpkins); and relay plantings or harvest short-duration crops within longer maturing crops (bush beans with corn; cucumbers with peppers; trees with vegetables suppress weed germination. Two rows of beans grown between maize rows gave good weed suppression and improved maize in unweeded crops. However, potato suppressed weeds well when inter-cropped with maize (Maina and Drennan, 1997).

2.5.3.4. Catch-cropping:

Catch-cropping refers to an agronomic technique in which a crop, that stimulates a high percentage of the parasite weed seeds to germinate, is grown in an infested field for several weeks until

the parasite has attached to its roots at which stage it is up-rooted to destroy the weed (Oswald et al. 1997).

2.5.3.5. Pre-sowing irrigation:

Pre-sowing irrigation is practiced to a limited extent to control annual weeds in field crops. Land is irrigated and shallow discing, prior to crop planting destroyed germinating weeds. This allows for a crop establishment in a relatively weed-free environment (Akubundu, 1987).

2.5.4. Biological control:

The objective of biological weed control is not the eradication of weeds but the reduction and long-term stabilization of weed density at a sub-economic level. Permanent control of weeds has been obtained in a sufficient number of cases to establish biological weed control as a valuable method of weed suppression (Schroeder, 1980). Biological control is based on the observation that natural enemies are of prime importance in limiting the distribution and abundance of plants. Intentionally or accidentally introduced without their specific natural enemies into areas outside their natural distribution, many plants become

economically important weeds (Harris, 1973). Biological control involves the use of one living species (the agent) to control an unwanted species (the target). The aim of biological control is to restore the natural balance between the pest and its environment by the introduction of natural enemies which can help control the pest to a level where it is no longer considered a problem (Elliott, 1999).

2.5.5. Chemical weed control:

Chemical methods include the use of organic and inorganic herbicides as foliar sprays, soil and water treatments, fumigation and stem application (Babiker, 1976). Herbicides can act on weed by contact or systemic action. They can also be residual and non residual. They can further be classified as grass weed killers or broad-leaved weed killers for selective or non-selective weed control. However, some of them are effective on both grass and broad-leaved weeds (Abdel Rasol, 1998). The herbicide label will indicate which plant species are susceptible to chemical and the method of application that can be used. Care should be taken in

the storage and handling of herbicides. The instructions on the label should always be read before use (Elliott, 1999).

2.5.6. Integrated weed control program:

No single method will control all weeds; Also the repeated use of one method permits a buildup of species not being controlled (Anon, 1986). So best weed control is usually achieved by a combination of two or more of these previous methods. Many times this combination of weed control methods is called an integrated weed control program (Tredaway and Colvin, 2000).

2.5.7. Prevention:

If effective weed control is achieved using the previous methods, one further step should be considered. This is preventing weeds from re- infesting the area (Tredaway and Colvin, 2000). The use of certified, registered, and foundation seed, or clean planting, material can not be over emphasized in preventing weeds from infesting fields. It is also important to clean equipment before entering field or when moving from one field to another (Tredaway and Clovin, 2000).

2.6. Use of herbicides in garlic:

Herbicides, combined with good cultural practices control many weed species in garlic. Herbicides may be applied before planting or after planting. Foliar-applied herbicides may be utilized after crop emergence (Fischer *et al*. 2000). Fischer *et al*. (2000) mentioned that pre plant treatments of Metam sodium would destroy most weeds present in garlic fields, also they mentioned that Paraquat and Glyphosate (Roundup) can be used before garlic is planted to control emerged weeds, Pendimethalin controls many annual grasses and broadleaf weeds when applied after planting garlic, and bromoxynil, sethoxydim, fluazifop-p-butyl Fusilade dethodim bromoxynil, sethoxydim, fluazifop-p-butyl (Fusilade) dethodim) as post-emergence treatments could be used in garlic fields. However they reported that bromoxynil is very effective for control of small broadleaf weeds, and garlic is more tolerant to bromoxiynil than onion (*Allium cipa*) and this herbicide can be used in garlic any time after garlic emerges but before it reaches 12 inches in height. Vora and Mehta (1999) observed that the lowest weed population in garlic in the weed-

free control followed by treatment with oxyfluorfen at 0.18 kg a.i/ha. + Hand weeding at 40 days, oxadiazon at 0.5 kg a.i/ha and fluchloralin at 0.9 kg a.i/ha + hand weeding at 40 days and 20, 40, 60 and 80 days. Field studies were carried out by Tewari *et al*. (1998) to compare the efficacy of pendimethalin (0.75 kg/ha), isoproturon (0.5 kg/ha), metolachlor (1.25 kg/ha) and oxyfluorfen (0.07 kg/ha) combined with or without manual weed control, to unweeded and hand-weeded plots (after 20 days, after 20 days and 40 days, and after 20, 40, 60 days) in local cultivar of garlic, and they found that pendimethalin, isoproturon and oxyfluorfen + hand-weeding resulted in 76-86 % weed control. Manul hand weeding twice resulted in similar clove yields as herbicide application. Herbicides + hand weeding increased clove yields significantly compared to herbicide application only. Clove yields were similar with hand weeding (3 times), and pendimethalin or oxyfluorfen + hand-weeding. Vora and Mehta (1998) study the efficacy of fluorfen at 0.9 kg a.i/ha, oxyfluorfen at 0.18 kg a.i/ha oxadiazon at 0.5 kg a.i/ha, alachlor at I kg a.i/ha and butachlor at I kg a.i/ha for weed control in garlic, and they found that the

highest bulb yield of garlic 71 g/ha resulted from the weed-free control, 57 to 65 g/ha from herbicide application coupled with hand-weeding at 40 days, also oxadiazon at 0.5 kg a.i/ha + hand-weeding at 40 days gave 87% weed control. Pendimethalin at 2.5 and 1.87 kg/ha and fluchloralin at the same concentration supplemented with one hoeing after 105 days from sowing, resulted in significant increases in bulb yield of garlic compared to the weed-free control, also linuron at 105 and 1 kg/ha gave comparable results (Sandhu *et al*. 1997). Qasem (1996) studies the effect of some herbicides on weed control in garlic. Post-emergence application of oxyfluprfen and oxadiazon at the 3 to 4 leaf stage resulted in garlic yield comparable to the weed-free crop. Pre-plant application of both herbicides was also effective in weed control and increased garlic yield over the other herbicide treatments. Weed biomass reduction was up to 55%. However, under rain fed condition and with a heavy population of wild oat (*Avena sterilis*), only oxyfluorfen increased garlic yield over the weed-infested control. Methabenzthiazuron applied pre-planting gave consistent results but a lower yield than oxfluorfen or

oxadiazon. For weed control in garlic pendimethalin and trifuralin (post-emergence) both applied at 6 liters/ha, resulted in reliable weed reductions and good garlic yield (Filippov and Treskina, 1994). Farghali *et al*. (1994) in Assiut university studied the effects of Ronstar (oxadiazon) at 2 litres /feddan, hand weeding 3 times at monthly intervals and no weeding on yield and quality of garlic, and they found that hand weeding resulted in the lowest number and weed weight of weeds followed by Goal. Hand weeding also resulted in the tallest garlic plants, and the highest bulb weight and total bulb yield, followed by Goal and then Ronstar. In Brazil a field experiment was conducted to evaluate the effect of herbicides on weeds that affect garlic plants well as its phytotoxicity on the cultivars Quiteria. The treatments including both pre-emergence and post-emergence herbicides treatments the results indicated that the most efficient treatments were the following: Liouron + fluazifop-p-butyl, linuron + sethoxydim and oxyfluorfen + alloxydim-sodium, which resulted in greater commercial bulb yields (Garcia *et al*. 1994). In field trials conducted in spain, Agil (propaquiza fop) at 1 to 1.5

litres/ha controlled many weed species in garlic (Martinez and Sugranes, 1993). In Italy Durante and Cuocolo (1989) mentioned that oxyfluorfen at 0.3 kg/ha and pendimethalin at 1.3 kg/ha were most effective against weed in garlic (Cv. Bianco Napoletano) when applied once post-emergence at the end of winter. Dacthal (chorthal-dimethyl + Furloe (chlorpropham) pre-emergence, provided weed-free conditions and achieved yields comparable to those obtained by early hand weeding, in garlic (cv. California late) planted on a clay loam soil infested mainly with *Malva parviflora* and *Capsella bursa-p-astoris* (Agamalian and Kurtz, 1989). Pre-emergent and post-emergent applications of chloroxuron, pendimethalin, bromoxynil, sethoxydim and fluazifop-p-butyl were applied to elephant garlic and silver garlic in Oregon to evaluate weed control and applied pre-emergent to weeds and the silver garlic but pos-emergent to elephant garlic. Weed control in silver garlic and elephant garlic with chloroxuron and pendimethalin applications resulted in 78 to 86% weed control. Bromoxynil was applied after weeds were too large resulting in poor weed control. Sethoxydin and fluazifop-p-butyl

did not control broad-leaved weeds. Phytotoxicity from chloroxuron, bromoxynil and pendimethalin were high for silver garlic and elephant garlic demonstrated little or no reduction in growth from phytotoxicity (William, 1988). In a series of trials with autumn (Cv. Zahorsky) and spring (Cv. Japo) crop garlic herbicides were applied in multiple applications against broad-leaved and grass weeds. The best weed control and highest yields in both cultivars were produced by Probe 75 W.P. (methazole) at 3 kg/ha or methazole at 3 kg/ha followed by Fusilade w.p (Fluazifopbuty) at 4 kg/ha about 10 days later (Janyska, 1986).

2.7. Herbicides used in this investigation:

2.7.1. Stomp:

Common name: pendimethalin

Chemical family: Dinitroaniline

Chemical name: N- (1-ethylpropyl)–3, 4-dimethyl-2, 6-dinitrobenenamine).

Stomp is used as pre-plant incorporated, pre emergence, and also as a post emergence herbicide to control annual weeds, in a range of crops such as cotton, groundnut, cereals, beans, sunflowers and

some vegetables (Anon, 1993). The herbicide is readily absorbed by the roots and shoots but only slightly translocated. Stomp inhibits cell division. Several biochemical processes can be altered such as photosynthesis, RNA and protein synthesis, lipid synthesis and oxidative phosphorylation (Roberts, 1982).Persistence of dinitroaniline in the soil may only be for a few weeks at low doses but higher rates activity can be detected for longer period (Roberts, 1982).

2.7.2. Goal:

Common name: Oxyflurofen

Chemical family: Diphenyl ether

Chemical name:

2-chloro-chloro-1-(3-ethoxy-4-nitropenoxy-

4(trifluoromethyl) benzene

Goal is used as a selective herbicide applied pre and post-emergence against annual weeds in beans, sun flower, citrus, onion, garlic, and other crops. It can persist in the soil for several months after application of higher rates to the soil surface. It is relatively insoluble in water and hence does not readily leach

(Roberts, 1982). Goal causes necrosis and some times chlorosis when applied to foliage, while pre-emergence application inhibits seed germination and early seedling growth and meristematic activity (Roberts, 1982). Exposure of the shoot zone to oxyflurofen herbicide caused much more injury to the plants than root exposure. There was a very little movement of the compound from the roots (Fadagomi and warren, 1977).

CHAPTER THREE

MATERIALS AND METHODS

Two field experiments were conducted during the winter seasons 1999/2000 and 2000/2001 in the Experimental Research Farm of the Faculty of Agriculture, University of Khartoum at Shambat (latitude 15º 40′ E, longitude 32° 32′ N and sea level elevation 380 m).

The soil was aclay loam with 30% and 1% organic matter. The pH was about 7.3-9.3 and the CEC value was 33 mmol/1oo g. The experimental site was ploughed, harrowed, leveled and then ridged in north and south direction and then divided into plots. The plot size was 4 meters×3.5 meters. Each plot contains 4 ridges.

A local cultivar's (Dongola) was used in the two seasons, Bulbs were obtained from the local market and cloves with similar sizes were selected. The cloves were planted manually 30 November in the two seasons at a rate of one clove per hole with the basal end down and the tip just at the soil surface, on both sides of the ridges. Inter-ridge spacing was 0.15 meters. Nitrogen fertilizer, in the form of urea was applied at the rate of 120 kg N/hectare, about half of it was applied at sowing, and the rest applied 60 days after sowing. Phosphorus fertilizer, in the form of super

phosphate was applied at the rate of 120 kg/hectare, at sowing. Irrigation was done in 7–10 days intervals depending on the prevailing weather condition.

In the experiment the herbicides pendimethalin in two rates, oxyfluorfen in two rates, mixture of pendimethalin and oxyfluorfen in two rates, and mixture of pendimethalin and oxyfluorfen in two rates followed by one supplementary hand weeding (30 days after sowing) was evaluated for weed control in garlic.

The following treatments were carried out:

1. Pendimethalin 4.2 kg ai/ha (as high rate)
2. Pendimethalin 2.1 kg ai/ha (as low rate)
3. Oxyfluorfen 0.5 kg ai/ha (as high rate)
4. Oxyfluorfen 0.25 kg ai/ha (as low rate)
5. Pendimethalin 2.1 kg ai/ha + Oxyfluorfen 0.25 kg ai/ha
6. Pendimethalin 4.2 kg ai/ha + Oxyfluorfen 0.5 kg ai/ha
7. (Pendimethalin 2.1 kg ai/ha + Oxyfluorfen 0.25 kg ai/ha) + HW
8. (Pendimethalin 4.2 kg ai/ha + Oxyfluorfen 0.5 kg ai/ha) + HW
9. Weed free check
10. Weedy check

The experiment was arranged in a randomized complete block with four replicates.

Aqueous solutions of the two herbicides were applied as pre-emergence sprays immediately after sowing using a knapsack sprayer calibrated to deliver 130 L/fedan. Some of the herbicide-treated plots were given one supplementary hand-weeding 30

days after sowing. For weed free check treatment, weed removed by hand continuously to keep the crop weed-free till harvest, for weedy check treatment, weed were allowed to grow till harvest.

Data collection:

Weeds:

Two counts were done 30 days and 60 days after sowing to determine the effect of herbicides treatments on weeds number and species. This was done by randomly placing a 0.25m×0.25m quadrate at eight places in each plot. Weed species and weed biomass were recorded.

Crop:

To evaluate the effect of herbicides treatments on crop growth, ten plants were selected randomly from each plot 60 days after sowing to determine, the number of leaves per plant, plant height (m), fresh weigh per plant (g), and dry weight per plant (g). The crop was harvested manually when it was fully mature time. The crop was stored in the laboratory for one week, then cured and topped, and the following data were recorded:

1. Total yield/ plot
2. Average bulb weight (g) by selecting 10 bulbs randomly from each treatment
3. Average clove number/ bulb by selecting 10 bulbs randomly from each treatment

Statistical analysis:

The collected data in this investigation were statistically analyzed according to Duncan's Multiple Range Test (D M R T).

CHAPTER FOUR

RESULTS

Effect of herbicides treatments on garlic growth:

It is evident from the results that garlic plant height was not significantly affected by the use of any of the herbicides, herbicide mixtures, and herbicide mixtures followed by one supplementary hand-weeding, and weed free check compared to weedy check in the two seasons (Table 1). Data of the

two seasons revealed that all herbicides, herbicide mixtures, and herbicide mixtures followed by one supplementary hand-weeding, and weed free check had no significant effects on the number of leaves per plant compared to weedy check (Table 2). Data of table 3 showed that the herbicide Stomp at its two rates, herbicide mixtures, and herbicide mixtures followed by one supplementary hand weeding, and weed free check had significantly increased

garlic fresh weight compared to the weedy check in the first season. But herbicide Goal 0.5 not significantly different from weedy check . Goal 0.25 significantly reduced the fresh weight per plant compared to weedy check. With the exception of the herbicide Goal at its low rate, all herbicides, herbicide mixtures, herbicide mixtures followed by one supplementary hand-weeding, and weed free check had significantly increase garlic fresh weight per plant

Table 1: Effect of herbicides treatments and supplementary hand weeding (once 4 weeks after sowing) on garlic Plant height in 99/2000 and 2000/2001 seasons.

Treatments Kg.ai/ha	**1999/2000**	**2000/2001**
	(cm)	**(cm)**
Stomp (2.1	**34.94 a**	**38.05 a**
Stomp (4.2)	**34.36 a**	**38.20 a**
Goal (0.25)	**32.43 a**	**37.28 a**
Goal (0.5)	**34.9 a**	**37.83 a**
Stomp (2.1)+Goal (0.25)	**34.82 a**	**39.40a**
Stomp (2.1)+Goal (0.25) +HW	**34.47 a**	**38.98 a**
Stomp ((4.2)+Goal (0.5)	**32.79 a**	**38.98 a**
Stomp (4.2)+Goal (0.5) +HW	**35.87 a**	**38.38 a**
Weed Free check	**31.82 a**	**38.48 a**
Weedy check	**33.42 a**	**38.13 a**
SE±	**0.73**	**0.36**

- **Means within a column followed by the same letter are not significantly different at the (0.05) level according to the Duncan's Multiple Range Test.**

- **HW=with supplementary hand weeding.**

Table 2: Effect of herbicides treatments and supplementary hand weeding (once 4 weeks after sowing) on garlic number of leaves/plant in 99/2000 and 2000/2001 seasons.

Treatments Kg.ai/ha	**1999/2000**	**2000/2001**

Stomp (2.1	**6.33 a**	**8.00 a**
Stomp (4.2)	**6.35 a**	**7.80 a**
Goal (0.25)	**6.55 a**	**7.85 a**
Goal (0.5)	**6.50 a**	**7.95 a**
Stomp (2.1)+Goal (0.25)	**6.30 a**	**7.93 a**
Stomp (2.1)+Goal (0.25) +HW	**6.30 a**	**8.05 a**
Stomp ((4.2)+Goal (0.5)	**6.78 a**	**7.60 a**
Stomp (4.2)+Goal (0.5) +HW	**6.43 a**	**8.15 a**
Weed Free check	**6.55 a**	**7.60 a**
Weedy check	**5.63 a**	**8.30 a**
SE±	**0.36**	**0.28**

- **Means within a column followed by the same letter are not significantly different at the (0.05) level according to the Duncan's Multiple Range Test**
- **HW=with supplementary hand weeding.**

Table 3: Effect of herbicides treatments and supplementary hand weeding (once 4 weeks after sowing) on garlic fresh weight/plant in 99/2000 and 2000/2001 seasons.

Treatments Kg.ai/ha	**1999/2000**	**2000/2001**
	(gm)	**(gm)**
Stomp (2.1	**6.55 e**	**10.35 e**
Stomp (4.2)	**7.12 c**	**11.70 c**
Goal (0.25)	**5.48 g**	**7.71 g**
Goal (0.5)	**6.22 f**	**10.64 d**
Stomp (2.1)+Goal (0.25)	**7.75 b**	**12.37 b**
Stomp (2.1)+Goal (0.25) +HW	**7.94 b**	**12.58 b**
Stomp ((4.2)+Goal (0.5)	**8.15 a**	**13.06 a**
Stomp (4.2)+Goal (0.5) +HW	**8.15 a**	**13.07 a**
Weed Free check	**6.8 d**	**11.06 d**
Weedy check	**6.2 f**	**8.68 f**
SE±	**0.06**	**0.21**

- **Means within a column followed by the same letter are not significantly different at the (0.05) level according to the Duncan's Multiple Range Test**
- **HW=with supplementary hand weeding.**

compared to the weedy check in the second season. Hand-weeding had no significant effect on herbicide mixtures followed

by one supplementary hand-weeding in both seasons. The herbicide mixtures was better than weed free check. Herbicide mixtures was better than one herbicide (Table 3). Data in Table 4 showed that all herbicides, herbicide mixtures, herbicide mixtures followed by one supplementary hand weeding, and weed free check had increased garlic dry weight per plant compared to the weedy check in the first season except herbicide Goal at its two rates. Garlic dry weight had significantly increased by the use of herbicides, herbicide mixtures, herbicide mixtures followed by one supplementary hand-weeding, and weed free check compared to the weedy check in the second season except by the use of herbicide Goal at its low rate (Table 4).

Effect of herbicides treatments on weeds:

Visual observations showed that the experiment sites were highly infested with the broad-leaved weeds *Datura innoxia* L., *Datura stramonium* L., and *Ammi majaus* L. in the two seasons.

It is evident from the result that all herbicides, herbicide mixtures, herbicide mixtures followed by one supplementary hand-weeding had achieved significant increase percentage weed control on broad- leaved in both seasons compared to weedy check and the highest percentage weed

control was achieved by weed free check (Table 5). In weed grasses all herbicides, herbicide mixtures herbicide mixtures followed by one supplementary hand-weeding, and weed free check showed significant increase in percentage control compared to weedy check in both seasons.

Table 4: Effect of herbicides treatments and supplementary hand weeding (once 4 weeks after sowing) on garlic dry weight/plant in 99/2000 and 2000/2001 seasons.

Treatments Kg.ai/ha	**1999/2000**	**2000/2001**
	(gm)	**(gm)**
Stomp (2.1	1.42 d	**1.76 c**
Stomp (4.2)	**1.49 cd**	**1.75 c**
Goal (0.25)	**1.18 f**	**1.30 d**
Goal (0.5)	**1.27 e**	**1.77 c**
Stomp (2.1)+Goal (0.25)	**1.52 c**	**1.84 bc**
Stomp (2.1)+Goal (0.25) +HW	**1.50 c**	**1.91 abc**
Stomp ((4.2)+Goal (0.5)	**1.74 a**	**2.01 ab**
Stomp (4.2)+Goal (0.5) +HW	**1.64 b**	**1.99 ab**
Weed Free check	**1.75 a**	**2.08 a**
Weedy check	**1.28 e**	**1.47 d**
SE±	**0.02**	**0.04**

- **Means within a column followed by the same letter are not significantly different at the (0.05) level according to the Duncan's Multiple Range Test.**
- **HW=with supplementary hand weeding.**

Table 5: Effect of herbicides treatments and supplementary hand weeding (once 4 weeks after sowing) on grasses weed control in garlic in 99/2000 and 2000/2001 seasons.

Treatments KG.AI/HA	Weed Control %			
	1999/2000		2000/2001	
	4 W A S	8 W A S	4 W A S	8 W A S
Stomp (2.1)	88 ed	83 d	85 cd	79 e
Stomp (4.2)	90 bc	86 d	85 cd	82 e
Goal (0.25)	78 e	78 e	66 e	73 f
Goal (0.5)	84 de	82 de	83 d	69 f
Stomp (2.1)+Goal (0.25)	91 bc	90 c	87 cd	87 d
Stomp (2.1)+Goal (0.25) +HW	93 b	93 bc	90 bc	93 bc
Stomp ((4.2)+Goal (0.5)	93 b	93 bc	87 cd	90 cd
Stomp (4.2)+Goal (0.5) +HW	93 b	94 b	93 b	94 b
Weed Free check	99 a	99 a	99 a	99 a

Weedy check	**0.0 f**	**0.0 f**	**0.0 f**	**0.0 f**
SE±	**1.32**	**1.06**	**1.13**	**1.01**

- **Means within a column followed by the same letter are not significantly different at the (0.05) level according to the Duncan's Multiple Range Test.**
- **HW=with supplementary hand weeding, WAS=week after sowing.**

(Table 6). In both seasons the total percentage of weed control had significantly increased by the use of all herbicides, herbicide mixtures, herbicide mixtures followed by one supplementary hand weeding, and weed free check compared to weedy check. The weed free check was the first treatment causing the highest total percentage weed control, and herbicide mixtures followed by one supplementary hand weeding was the second (Table 7). Table 8 showed that all herbicides, herbicide mixtures herbicide mixtures followed by one supplementary hand weeding had significantly reduced weed dry weight (g/m^2) compared to weedy check in both seasons.

Effect of herbicides on garlic yield:

Data in table 9 showed that all herbicides, herbicide mixtures, herbicide mixtures followed by one supplementary hand-weeding, and

weed free check significantly increased bulb fresh weight compared to weedy check in both seasons. In both seasons all herbicides, herbicide mixtures, herbicide mixtures followed by one supplementary hand weeding, and weed free check significantly increased number of cloves per bulb compared to weedy check (Table 10). In table 11 data showed that all herbicides, herbicide mixtures, herbicide mixtures followed by one supplementary hand-weeding, and weed free check had increased garlic yield (tones per hectare) compared to weedy check in both seasons.

Table 6: Effect of herbicides treatments and supplementary hand weeding (once 4 weeks after sowing) on broad-leaved weed control in garlic in 99/2000 and 2000/2001 seasons.

Treatments *KG.AI/HA*	Weed Control %			
	1999/2000		2000/2001	
	4 W A S	8 W A S	4 W A S	8 W A S
Stomp (2.1)	**85 de**	**71 f**	**86 cd**	**66 e**
Stomp (4.2)	**87 d**	**76 e**	**88 bc**	**68 e**
Goal (0.25)	**80 f**	**52 h**	**73 e**	**53 g**
Goal (0.5)	**84 e**	**66 g**	**83 e**	**59 f**
Stomp (2.1)+Goal (0.25)	**90 c**	**76 e**	**90 bc**	**74 d**
Stomp (2.1)+Goal (0.25) +HW	**93 b**	**89 c**	**92 b**	**79 c**

Stomp ((4.2)+Goal (0.5)	**92 bc**	**84 d**	**89 bc**	**85 b**
Stomp (4.2)+Goal (0.5) +HW	**93 b**	**94 b**	**92 b**	**87 b**
Weed Free check	**99 a**	**99 a**	**99 a**	**99 a**
Weedy check	**0.0 g**	**0.0 i**	**0.0 f**	**0.0 h**
SE±	**0.74**	**0.89**	**1.40**	**0.91**

- **Means within a column followed by the same letter are not significantly different at the (0.05) level according to the Duncan's Multiple Range Test.**
- **HW=with supplementary hand weeding, WAS=week after sowing.**

Table 7: Effect of herbicides treatments and supplementary hand weeding (once 4 weeks after sowing) on total weed control in garlic in 99/2000 and 2000/2001 seasons.

Treatments *KG.AI/HA*	**Weed Control %**			
	1999/2000		**2000/2001**	
	4 W A S	**8 W A S**	**4 W A S**	**8 W A S**
Stomp (2.1)	**80 c**	**77 f**	**86 e**	**72 e**
Stomp (4.2)	**85 c**	**81 e**	**87 de**	**74 e**
Goal (0.25)	**81 c**	**67 h**	**70 g**	**60 g**

Goal (0.5)	**82 c**	**72 g**	**78 f**	**65 f**
Stomp (2.1)+Goal (0.25)	**91 b**	**84 d**	**89 cd**	**80 d**
Stomp (2.1)+Goal (0.25) +HW	**93 b**	**88 c**	**90 bc**	**86 c**
Stomp ((4.2)+Goal (0.5)	**92 b**	**90 c**	**88 de**	**87 bc**
Stomp (4.2)+Goal (0.5) +HW	**93 b**	**94 b**	**92 b**	**90 b**
Weed Free check	**99 a**	**99 a**	**99 a**	**99 a**
Weedy check	**0.0 d**	**0.0 i**	**0.0 h**	**0.0 h**
SE±	**1.39**	**0.61**	**0.65**	**1.68**

- **Means within a column followed by the same letter are not significantly different at the (0.05) level according to the Duncan's Multiple Range Test.**
- **HW=with supplementary hand weeding, WAS=week after sowing.**

Table 8: Effect of herbicides treatments and supplementary hand weeding (once 4 weeks after sowing) on weed dry weight (g/m2) in 99/2000 and 2000/2001 seasons.

Treatments Kg.ai/ha	**1999/2000**	**2000/2001**

Stomp (2.1	**113.50 b**	**132 b**
Stomp (4.2)	**93.10 cd**	**85.95 c**
Goal (0.25)	**164 b**	**138.05 b**
Goal (0.5)	**142.60 b**	**135.35 b**
Stomp (2.1)+Goal (0.25)	**85.30 c**	**79.25 d**
Stomp (2.1)+Goal (0.25) +HW	**66.40 de**	**38.75 f**
Stomp ((4.2)+Goal (0.5)	**73.30 e**	**54.3 e**
Stomp (4.2)+Goal (0.5) +HW	**47.00 e**	**32.00 g**
Weed Free check	**0.00 f**	**0.00 h**
Weedy check	**307.80 a**	**206.05 a**
SE±	**1.31**	**1.91**

- **Means within a column followed by the same letter are not significantly different at the (0.05) level according to the Duncan's Multiple Range Test.**
- **HW=with supplementary hand weeding.**

Table 9: Effect of herbicides treatments and supplementary hand weeding (once 4 weeks after sowing) on garlic bulb weight in 99/2000 and 2000/2001 seasons.

Treatments Kg.ai/ha	**1999/2000**	**2000/2001**
	(gm)	**(gm)**
Stomp (2.1	**13.05 ef**	**15.42 e**
Stomp (4.2)	**13.52 e**	**17.52 de**
Goal (0.25)	**10.62 g**	**9.15 g**
Goal (0.5)	**11.21 fg**	**12.35 f**
Stomp (2.1)+Goal (0.25)	**15.89 d**	**19.82 d**
Stomp (2.1)+Goal (0.25) +HW	**19.33 c**	**22.53 c**
Stomp ((4.2)+Goal (0.5)	**17.14 d**	**23.71 c**
Stomp (4.2)+Goal (0.5) +HW	**23.29 b**	**26.59 b**
Weed Free check	**25.36 a**	**29.06 a**
Weedy check	**5.38 h**	**7.50 g**
SE±	**0.66**	**0.73**

- **Means within a column followed by the same letter are not significantly different at the (0.05) level according to the Duncan's Multiple Range Test.**
- **HW=with supplementary hand weeding.**

Table 10: Effect of herbicides treatments and supplementary hand weeding (once 4 weeks after sowing) on garlic number of cloves/bulb in 99/2000 and 2000/2001 seasons.

Treatments Kg.ai/ha	**1999/2000**	**2000/2001**
Stomp (2.1	**20.92 c**	**22.88 d**
Stomp (4.2)	**20.43 c**	**23.4 cd**
Goal (0.25)	**16.48 d**	**19.05 e**
Goal (0.5)	**17.48 d**	**19.53 e**
Stomp (2.1)+Goal (0.25)	**21.8 d**	**24.9 bc**
Stomp (2.1)+Goal (0.25) +HW	**24.28 ab**	**25.75 ab**
Stomp ((4.2)+Goal (0.5)	**23.85 b**	**25.5 ab**
Stomp (4.2)+Goal (0.5) +HW	**25.0 ab**	**26.25 ab**
Weed Free check	**25.75 a**	**27.05 a**
Weedy check	**11.58 e**	**15.83 f**
SE±	**0.57**	**0.60**

- **Means within a column followed by the same letter are not significantly different at the (0.05) level according to the Duncan's Multiple Range Test.**
- **HW=with supplementary hand weeding.**

Table 11: Effect of herbicides treatments and supplementary hand weeding (once 4 weeks after sowing) on garlic yield tonnes/ha in 99/2000 and 2000/2001 seasons.

Treatments Kg.ai/ha	**1999/2000**	**2000/2001**
Stomp (2.1	**0.66 g**	**0.95 de**
Stomp (4.2)	**0.7 f**	**1.02 cd**
Goal (0.25)	**0.59 i**	**0.78 e**
Goal (0.5)	**0.60 h**	**0.81 e**
Stomp (2.1)+Goal (0.25)	**0.94 e**	**1.15 bcd**
Stomp (2.1)+Goal (0.25) +HW	**1.08 c**	**1.37 b**
Stomp (4.2)+Goal (0.5)	**0.96 d**	**1.21 bc**
Stomp (4.2)+Goal (0.5) +HW	**1.10 b**	**1.37 b**
Weed Free check	**1.19 a**	**1.67 a**
Weedy check	**0.39 j**	**0.52 f**
SE±	**0.001**	**0.05**

- **Means within a column followed by the same letter are not significantly different at the (0.05) level according to the Duncan's Multiple Range Test.**
- **HW=with supplementary hand.**

CHAPTER FIVE

Discussion

Generally the herbicides Stomp, Goal, and Stomp mixed with Goal had excellent and lasting effects on the control of annual weeds, but the performance of these herbicides was greatly effected by the presence of the tolerant broad-leaved weeds *Datura stramonium* and *Datura innoxia* in the two seasons, specially herbicide Goal at its low rate which gave reduction in garlic plant fresh weight in the two seasons, and reduction in garlic dry weight in the first season.

Herbicide Goal alone gave satisfactory control of annual broad-leaved and grass weeds in both seasons. Herbicide Stomp alone showed excellent effect on annual broad-leaved and grasses weeds in both seasons. Similar results were obtained by Bell *et al.* (2000), William (1988), and Durante and Cuocolo (1989).

On the other hand herbicides mixtures gave better weed control compared to single herbicide. Similar finding were obtained by Agamalian and Kurtz (1989), Janyska (1986),Garcia *et al*. (1994), Arnold *et al*. (1993), and Idris

(2000). Blanco (1981) found that the herbicide dinoseb at 2kg/ha in tank-mixture with pendimethalin at 1kg/ha gave the best result for controlling both grassy and broad-leaved weeds. A/magid (1997) reported that, mixing herbicides had greater efficacy than using a single herbicide. The herbicides application followed by a single supplementary hand weeding gave the best result among all tested treatments. Vora and Mehta (1999) observed lowest weed population in garlic plots treated with Goal followed by hand-weeding, also Tewari *et al*. (1998) found that pendimethalin, isoproturon and oxyfluorfen followed by hand-weeding resulted in 76-86% weed control. This study showed that herbicides followed by one supplementary hand weeding reduce weeds dry weight compared to single herbicide. Similar findings were found by Farghali *et al.* (1994), they found that Goal followed by hand weeding resulted in the lowest number and weight of weeds.

Weeds competition in garlic is severe because garlic germinates and emerges slowly and its cylindrical-upright leaves do not shade the soil to suppress weed growth. According to this investigation, unrestricted weeds growth reduce garlic yield by 33 to 64%. Mohamed and Nourai (1997) mentioned that reductions in garlic due to weeds infesting were ranging from 22- 26 %.

This study showed that early removal of weeds by use of pre-emergence herbicides such as Stomp, Goal, Stomp mixed with Goal, and Stomp mixed

with Goal followed by one supplementary hand-weeding at 4 weeks after sowing resulted in 51 to 221% increase in bulb yield compared to weedy check. The increase of garlic yield as a result of application of these herbicides was mainly due to an increased number of cloves per bulb and/or increase bulb size. The highest bulb yield was obtained by Stomp mixed with Goal followed by one supplementary hand weeding with two rates in both seasons. Increase in garlic yield with application of herbicides followed by supplementary hand-weeding was reported by Tewari *et al*. (1998) who mentioned that Stomp and Goal followed by hand-weeding increased clove yields significantly compared to herbicide application only, similar findings were obtained by Vora and Mehta (1998), and Saudhu et al. (1997). The next best result was obtained by the herbicide Stomp mixed with herbicide Goal similar results have been reported by Garcia et al. (1994). The herbicide Stomp alone and Goal alone gave better yield than what similar results were obtained by Farghali *et al*. (1994), Gasem (1996), Garcia *et al*. (1994), and Darante and Cuocolo (1989).

The increase in final yield of garlic in herbicide-treated plots due to better weed control. The effectiveness of herbicides mixtures followed by one supplementary hand weeding at 4 weeks after sowing and selectivity of Stomp and Goal in garlic make these herbicides treatments possible candidates for the control of weeds in Sudan.

CONCLUSIONS

1. Unrestricted weed growth reduced bulb yield of garlic by 33 to 64%
2. Garlic showed high tolerance to the herbicides: Stomp, Goal and Stomp mixed with Goal.
3. Herbicides Stomp, Goal and their mixture-displayed moderate to excellent activity against a wide spectrum of weeds.
4. Herbicides mixtures gave better weed control than a single herbicide.
5. Use of herbicides followed by one supplementary hand weeding (4 weeks after sowing) is necessary to control the tolerant weeds.
6. The highest yield of garlic was achieved by the herbicide Stomp mixed with Goal followed by one supplementary hand weeding at 4 weeks after sowing.
7. The effectiveness of these herbicides against weeds and their high selectivity in garlic, taken in conjunction with the adverse effects of weeds on garlic coupled with scarcity of labors and its high cost, make these herbicides possible candidates for the control of weeds in garlic in the Sudan.

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Appendix (1): Mean square of garlic plant height in 99/2000 and 2000/2001 seasons.

Source of variation	Degrees of freedom	99/2000	2000/2001
Block	3	1.12	0.03
Treatment	9	6.78 ns	1.51 ns
Error	27	2.12	1.31
C.V%		4.29%	2.98%

Appendix (2): Mean square of garlic number of leaves/plant in 99/2000 and 2000/2001 seasons.

Source of variation	Degrees of freedom	99/2000	2000/2001
Block	3	0.025	0.10
Treatment	9	0.58 ns	0.20 ns
Error	27	0.27	0.76
C.V%		7.93%	11.01%

Appendix (3): Mean square of garlic fresh weight/plant in 99/2000 and 2000/2001 seasons.

Source of variation	Degrees of freedom	99/2000	2000/2001
Block	3	0.01	0.05
Treatment	9	3.51**	13.26**
Error	27	0.01	0.18
C.V%		1.65%	3.85%

Appendix (4): Mean square of garlic dry weight/plant in 99/2000 and 2000/2001 seasons.

Source of variation	Degrees of freedom	99/2000	2000/2001
Block	3	0.001	0.03
Treatment	9	0.16**	0.24**
Error	27	0.002	0.02
C.V%		3.10%	7.40%

Appendix (5): Mean square of grasses weed control in 99/2000 and 2000/2001 seasons.

		1999/2000		2000/2001	
Source of variation	**Degrees of freedom**	**4WAS**	**8WAS**	**4WAS**	**8WAS**
Block	**3**	**4.92**	**1.67**	**0.09**	**0.65**
Treatment	**9**	**1959.75****	**1974.39****	**1870.16****	**1948.06****
Error	**27**	**6.97**	**4.46**	**5.15**	**4.12**
C.V%		**4.00%**	**3.25%**	**3.62%**	**3.24%**

Appendix (6): Mean square Of broad-leaved weed control in 99/2000 and 2000/2001 seasons.

		1999/2000		2000/2001	
Source of variation	**Degrees of freedom**	**4WAS**	**8WAS**	**4WAS**	**8WAS**
Block	**3**	**3.25**	**1.33**	**0.74**	**5.36**
Treatment	**9**	**1939.1****	**1937.77****	**1880.77****	**1749.41****
Error	**27**	**2.22**	**3.18**	**7.83**	**3.32**
C.V%		**2.27%**	**3.05%**	**4.34%**	**3.27%**

Appendix (7): Mean square of total weed control in 99/2000 and 2000/2001 seasons.

		1999/2000		2000/2001	
Source of variation	**Degrees of freedom**	**4WAS**	**8WAS**	**4WAS**	**8WAS**
Block	**3**	**10.88**	**0.21**	**0.13**	**2.85**
Treatment	**9**	**2038.98****	**2018.63****	**1980.15****	**1911.85****
Error	**27**	**7.72**	**1.47**	**1.70**	**1.83**
C.V%		**4.28%**	**1.97%**	**2.06%**	**2.31%**

Appendix (8): Mean square of weed dry weight (g/m) in 99/2000 and 2000/2001 seasons.

Source of variation	Degrees of freedom	99/2000	2000/2001
Block	3	16.05	1.85
Treatment	8	11643.64**	11611.88**
Error	24	6.85	14.62
C.V%		2.32%	3.89%

Appendix (9): Mean square of garlic bulb weight in 99/2000 and 2000/2001 seasons.

Source of variation	Degrees of freedom	99/2000	2000/2001
Block	3	0.08	0.03
Treatment	9	145.81**	212.72**
Error	27	1.76	2.14
C.V%		8.57%	7.67%

Appendix (10): Mean square of garlic number of cloves/bulb in 99/2000 and 2000/2001 seasons.

Source of variation	Degrees of freedom	99/2000	2000/2001
Block	3	0.52	0.27
Treatment	9	82.17**	54.99**
Error	27	1.32	1.42
C.V%		5.52%	5.18%

Appendix (11): Mean square of garlic yield tones/ha in 99/2000 and 2000/2001 seasons.

Source of variation	Degrees of freedom	99/2000	2000/2001
Block	3	0.00	0.02
Treatment	9	0.29	0.46
Error	27	0.00	0.02
C.V%		0.59%	13.18%

Appendix table (12) List of predominant weedsin the experimental Site in season 99/2000

Sida alba	أم شديدة
Triantherna spp	ربعة
Chrozophora plicata	تروب
Protulaca oleraceae	الرجلة

Anstolchia bacteolaa	أم جلاجل
Ipomea cordofana	التبر
Xanthium brasilicum	الرانتوك
Hibiscus lobatus	ويكة الفيل
Hibiscus riouum	ويكة الخلاء
Euphorbia spp.	أم لبينة
Brachiaria eruciformis	أم سليكة
Phyllanthus maderaspaten	عرقانة كبيرة
Phyllanthus niruri	عرقانة صغيرة
Amaranthus viridis L.	لسان طير كبير
Amaranthus graecizans L.	لسان طير صغير
Datura stramonium	السيكران
Datura innoxia	السيكران

Appendix table (13) List of predominant weedsin the experimental Site in season 2000/2001.

Sida alba	أم شديدة
Triantherna spp	ربعة
Chrozophora plicata	تروب
Protulaca oleraceae	الرجلة

Anstolchia bacteolaa	**أم جلاجل**
Ipomea cordofana	**التبر**
Xanthium brasilicum	**الرانتوك**
Hibiscus lobatus	**ويكة الفيل**
Hibiscus riouum	**ويكة الخلاء**
Euphorbia spp.	**أم لبينة**
Brachiaria eruciformis	**أم سليكة**
Phyllanthus maderaspaten	**عرقانة كبيرة**
Phyllanthus niruri	**عرقانة صغيرة**
Amaranthus viridis L.	**لسان طير كبير**
Amaranthus graecizans L.	**لسان طير صغير**
Datura stramonium	**السيكران**
Datura innoxia	**السيكران**

Stomp (2.1)	**85 de**	**71 f**	**86 cd**	**66 e**
Stomp (4.2) Goal (0.25)	**87 d**	**76 e**	**88 bc**	**68 e**
Goal (0.5)	**80 f**	**52 h**	**73 e**	**53 g**
Stomp (2.1)+Goal (0.25)	**84 e**	**66 g**	**83 e**	**59 f**
Stomp (2.1)+Goal (0.25) +HW	**90 c**	**76 e**	**90 bc**	**74 d**
Stomp ((4.2)+Goal (0.5)	**93 b**	**89 c**	**92 b**	**79 c**
Stomp (4.2)+Goal (0.5) +HW	**92 bc**	**84 d**	**89 bc**	**85 b**
Weed Free check	**93 b**	**94 b**	**92 b**	**87 b**
Weedy check	**99 a**	**99 a**	**99 a**	**99 a**
SE±	**0.0 g**	**0.0 i**	**0.0 f**	**0.0 h**

	0.74	**0.89**	**1.40**	**0.91**

- **Means within a column followed by the same letter are not significantly different at the (0.05) level according to the Duncan's Multiple Range Test.**
- **HW=with supplementary hand weeding, WAS=weeks after sowing.**

Table 7: Effect of herbicides treatments and supplementary hand weeding (once 4 weeks after sowing) on total weed control in garlic in 99/2000 and 2000/2001 seasons.

Treatments **Kg.ai/ha**	**Weed Control %**			
	1999/2000		**2000/2001**	
	4 W A S	**8 W A S**	**4 W A S**	**8 W A S**

Stomp (2.1)	**80 c**	**77 f**	**86 e**	**72 e**
Stomp (4.2) Goal (0.25)	**85 c**	**81 e**	**87 de**	**74 e**
Goal (0.5)	**81 c**	**67 h**	**70 g**	**60 g**
Stomp (2.1)+Goal (0.25)	**82 c**	**72 g**	**78 f**	**65 f**
Stomp (2.1)+Goal (0.25) +HW	**91 b**	**84 d**	**89 cd**	**80 d**
Stomp ((4.2)+Goal (0.5)	**93 b**	**88 c**	**90 bc**	**86 c**
Stomp (4.2)+Goal (0.5) +HW	**92 b**	**90 c**	**88 de**	**87 bc**
Weed Free check	**93 b**	**94 b**	**92 b**	**90 b**
Weedy check	**99 a**	**99 a**	**99 a**	**99 a**
SE±	**0 d**	**0 I**	**0 h**	**0 h**

	1.39	**0.61**	**0.65**	**0.68**