SENSITIVITY OF BROCCOLI *(Brassica oleracea* var. cymosa*)* HYBRID SEEDLINGS TO SELECTED SOIL APPLIED HERBICIDES UNDER SIMULATED THERMOPERIODS AND HUMIDITY OF MAGALIESBURG

By

EMMANUEL IFEANYI EGBUEZE

STUDENT NUMBER: 58523936

A dissertation submitted in fulfilment of the academic requirements for the degree of

MASTER OF SCIENCE IN AGRICULTURE

in the

Department of Agriculture and Animal Health,

College of Agriculture and Environmental Sciences

at the

UNIVERSITY OF SOUTH AFRICA

Supervisor : Prof G Prinsloo

Co-supervisor: Dr R.C. Y Awumey

October 2021

DECLARATION

I, **Emmanuel IfeanyiEgbueze**, do hereby declare that the work presented in this Dissertation entitled **"SENSITIVITY OF BROCCOLI *(Brassica oleracea* var. cymosa*)* HYBRID SEEDLINGS TO SELECTED SOIL APPLIED HERBICIDES UNDER SIMULATED THERMOPERIODS AND HUMIDITY OF MAGALIESBURG"** is original work done by myself under the mentorship of my supervisors. Additionally, I declare that the work presented herein has not been published or submitted at any other institution as part of the requirements for any degree programme. Any literature that has been cited in this Dissertation for research work conducted by other individuals has been given due acknowledgment and listed in the reference section. I also certify that I have complied with the rules, requirements, procedures, and policies of the University of South Africa.

Candidate : EMMANUEL IFEANYI EGBUEZE

Student Number : 58523936

Signature:………………………………………..

Place : University of South Africa, Florida Science Campus

Date : October 2018

DEDICATION

I dedicate this study to my precious wife, Uloma Peace for her solid spiritual and physical support and Love. To our special sons, Jeffrey and Jethro for their extreme understanding and patience in affording me the needed space to focus on my MSc research work. I humbly do believe that my sacrifice will advance the quality of our lives in the nearest future. Most importantly, I am eternally very grateful to the Almighty God for granting me the grace to do this MSc research work.

ACKNOWLEDGEMENTS

All gratitude and thanks to the Almighty God for granting me this opportunity to further my studies, for the strength and the wisdom in doing my studies. I appreciate the kind assistance of my caretaker supervisor, Prof G. Prinsloo.I sincerelythank and appreciatemy major supervisor, Mr.M. Makungu for his intellectual advice, guidance, and supervision during the period of my research. I equally thank Prof F. N Mudau for supervising me at a time my main supervisor was unavailable. Also, I thank Dr. R.C.Y Awumey for who stood as co-supervisor of this study.

The staff at the University of South Africa, Horticulture Centre Greenhouse, Department of Agriculture and Animal Health for the remarkable support which they provided. The seed and chemical companies (Garden Master, Villa crop, Laeveld, and Nulandis) for providing advice and information on chemicals used in this study. Mr. Udoka also deserves an acknowledgment for allowing me to get desired Magaliesburg soil from the Magaliesburg municipality farm to undertake this study.

I can’t ignore appreciating my family especially my ever-loving mum Mrs. Akole Wilson, my siblings Khiki, Hervey, Sonia, Ula, Blessing, and Chukwunenye for their immense prayers, goodwill messages and encouraging words.

To my treasured family and friends, Rodney and Monique Hill, Treza Dos Santos this academic endeavor is also dedicated to you; I immensely thank you for the prayers, motivation during this study and for standing by me throughout the journey. Thank you.

LIST OF ABBREVIATIONS

Ai	....	Active Ingredient
ANOVA	....	Analysis of Variance
ARC	....	Agricultural Research Council
Br	....	Broccoli
Clo	....	Clomazone Herbicide
CV	....	Coefficient of Variation
DAP	....	Days After Planting
DAT	………….	Days After Treatment
EC	....	Emulsifiable Concentrate Formulation
Hal	....	HalosulfuronHerbicide
Ha	…………...	Hectare
H	....	Herbicide
LSD	....	Least Significant Difference
M	....	Marine Cauliflower Hybrid
Ma ms	…………..	Metres above Mean Sea Level
Met	....	Metolachlor Herbicide
OC	…………..	Organic component

Oxa	....	Oxadiazon Herbicide
POST	…………..	Post emergence
PPI	……………	Preplanting incorporated
PPO	…………..	Protoporphyrin oxidase
PRE	…………….	Pre emergence
RCBD	....	Randomized Complete Block Design
SC	....	Suspension Concentrate Formulation
Tukey's HSD	....	Tukey's Honestly Significant Difference Test

TABLE OF CONTENTS

List of Figures

LIST OF TABLES

ABSTRACT

This study was conducted under a South African controlled environment to determine the sensitivity of direct seeded broccoli hybrid to four pre-emergence herbicides at seven application rates, Metolachlor at (0.4, 0.8, 1.2, 1.6,2.0,2.4 and 2.8l/ha), Clomazone (1.0, 2.0, 3.0, 4.0, 5.0 6.0 and 7.0 ppm/ha),Oxadiazon (0.25, 0.5, 1.0, 1.5, 1.75, 2.0 and 2.5 l/ha), Halosulfuron (0.015, 0.025, 0.040, 0.055, 0.070, 0.085 and 0.1l/ha) and an untreated non-herbicide control, which was demonstrated using RBCD and replicated three timesin a greenhouse pot experiment between June and September 2017.Clomazone and Metolachlor herbicides caused unacceptable injury (greater than 25%) at the proposed dose of each herbicide appliedat 7, 14, and 21 DAT.Oxadiazon at 7 and14 DAP caused a greater visual injury and also reduced plant vigor by 50%.Halosulfuron caused a 10% visual injury..Broccoli hybrid was tolerant to halosulfuron at 0.055 and 0.070l/ha.

Keywords: Broccoli; Sensitivity; Metolachlor; Oxadiazon; Clomazone; Halosulfuron; visualinjurysymptoms,pre-plantingincorporate,Pre-emergence.

ABSTRACT

Lolu cwaningo lwenziwe ngaphansi kwemvelo elawulwayo yaseNingizimu Afrika ukuze kutholwe ukuzwela kwehybrid ye-broccoli enembewu eqondile emithini yokubulala ukhula emine ngaphambi kokuhluma ngezilinganiso zokufaka eziyisikhombisa, i-Metolachlor ku-(0.4, 0.8, 1.2, 1.6,2.0,2.4 kanye no-2.8l/ha), I-Clomazone (1.0, 2.0, 3.0, 4.0, 5.0 6.0 kanye no-7.0 ppm/ha), i-Oxadiazon (0.25, 0.5, 1.0, 1.5, 1.75, 2.0 kanye no-2.5 l/ha), i-Halo1025, 0.05, 0.0, 0.0, 0. , 0.085 kanye no-0.1l/ha) kanye nokulawula okungalashiwe okungabulali ukhula, okuboniswe kusetshenziswa i-RBCD futhi kwaphindaphindwa kathathu ocwaningweni lwebhodwe elibamba ukushisa phakathi kukaJuni noSepthemba 2017. Imithi yokubulala ukhula ye-Clomazone ne-Metolachlor idale ukulimala okungamukeleki (okungaphezu kuka-25%) umthamo ohlongozwayo womuthi ngamunye osetshenziswa ku-7, 14, kanye no-21 DAT.I-Oxadiazon ku-7 kanye ne-14 DAP ibangele ukulimala okubonakalayo okukhulu futhi yanciphisa amandla esitshalo ngo-50%.I-Halosulfuron ibangele ukulimala kokubona okungu-10%. 0.070l/ha.

Amagama angukhiye: I-Brokholi; Ukuzwela; I-Metolachlor; i-oxadiazon; I-Clomazone; I-halosulfuron; izimpawu zokulimala okubukwayo, ukutshala kwangaphambi kokutshala kuhlanganisa, Ukuvela kwangaphambili.

ABSTRACT

Hierdiestudie is uitgevoeronder 'n Suid-Afrikaanse beheerde omgewing om die sensitiwiteit van direktesaad broccoli-baster vir viervoor-opkoms onkruiddoders te bepaal teen sewe toedieningshoeveelhede, Metolachlor by (0.4, 0.8, 1.2, 1.6, 2.0, 2.4 en 2.8l/ ha) Clomazone (1.0, 2.0, 3.0, 4.0, 5,0 6,0 en 7,0 dpm/ha), Oxadiazon (0.25, 0.5, 1.0, 1.5, 1.75, 2.0 en 2.5 l / ha) Halosulfuron (0.015, 0,025, 0,040, 0,055, 0,070, 0,085 en 0,1l/ha) en 'n onbehandelde beheerkontrole, wat met RBCD gedemonstreer is en drie keer herhaal is in 'n kweekhuispot-eksperiment tussen Junie en September 2017. Clomazoneen Metolachlor onkruiddoders het onaanvaarbare skade veroorsaak (meer as 25%) teen die voorgestelde dosis van elke onkruiddoder toegedien op 7, 14, en 21 DNP. Oxadiazon teen 7 en14 DNP het 'n groter visuele skade veroorsaaken die plantkrag met 50% verminder. Halosulfuron het 'n 10% visuele skade veroorsaak. Broccoli-baster was verdraagsaam tot Halosulfuron by 0,055 en 0,070l/ha.

Sleutelwoorde: Broccoli; Sensitiwiteit; Metolachlor; Oxadiazon; Clomazone; Halosulfuron; visueleskadesimptome, voortplanting, Vooropkoms.

CHAPTER 1

1.0: INTRODUCTION

1.1: Background Of Study

Broccoli (*Brassica oleracea* var. cymosa) also called the green beauty by (Owis, 2015) originated from Italy, more than 2,000 years ago. Broccoli is classified in the italic cultivar group of the species *Brassica oleracea*. The term broccoli comes from the Italian plural of broccoli, which means "the flowering crest of a cabbage", and is the diminutive form of brocco, meaning "small nail" or sprout". Broccoli has large flower heads, usually green in color, arranged in a tree-like structure branching out from a thick, edible stalk. The mass of flower heads is surrounded by leaves. Broccoli resembles cauliflower, which is a different cultivar group of the same species.

It has become quite interesting that broccoli is in high demand in southern Africa especially South Africa because of its high organoleptic properties and high nutritive value (Feher, 1986). Shortages in the supply of these vegetables have been based on its propagation mechanisms which include weeds management that increases the cost of production from seed to maturity and its nature of preservation hence it is a highly perishable crop. Broccoli is known to be a cool-weather crop that does quite poorly during hot or summer weather and South Africa has cooler weather, so it strives well during the cool season and it is in shortage during the summer season.

A simulated environmental experiment was devised to understudy its sensitivity to herbicides for weed control using different kinds of herbicides either as pre-planting and pre-emergence application on broccoli simulating the mean monthly temperatures during cool seasons which are the best growing seasons for broccoli production municipalities of South Africa including Magaliesburg (Gauteng Province with a mean monthly temperature of 21°C)

Broccoli and cauliflower are both related to cabbage and mustard, and some varieties of each are sold as the other. In appearance, most cauliflower has closely bunched tight masses that appear together on stems. Broccoli's flower masses are more loosely distributed so that it's possible to see space in between each stalk. The two vegetables have some similarities when they are cooked, in both taste and smell. Cauliflower is more likely to have an overall delicate taste, and broccoli tends to taste “greener” with a stronger flavor.

1.2: BroccoliTaxonomy And Botany

Broccoli (*Brassica oleracea* var. cymosa), have a common origin in a variety of wild forms of *Brassica oleracea* group of cultivated cole crops (Gray, 1982). Broccoli is believed to have evolved in the east coast region of the Mediterranean basin (Gray, 1982). Broccoli appears to be linked to other brassica families (Gómez-Campo & Gustafsson, 1991) Brassicaceae family include cabbage, broccoli, sprouts, mustard, rapeseeds, and brussels (Sharma, 2004). The many varieties show considerable diversity in form, with different parts of the plant being consumed as vegetables. The term broccoli is an Italian word derived from the Latin brachium which means an arm or branch (Boswell, 1949). Italians use the term broccoli to describe young edible floral shoots on Brassica plants including cabbages and turnips and were originally applied to sprouting forms but now include heading forms, which develop a large, single, terminal inflorescence. Broccoli is recognized by its large flower heads, usually green in color, arranged in a tree-like structure that is seen to be branching out from a thick, edible stalk. The bunch of flower heads is surrounded by leaves. Broccoli curd is formed from a packed-together flower head and produces a green curd that rapidly develops into a bunch of fertile flower buds (Biggs, 1993). There are three commonly grown types of broccoli. The most familiar is Calabrese broccoli, often referred to simply as “broccoli”, named after Calabria in Italy. It has large (10 to 20 cm) green heads and thick stalks. Broccoli is a very important vegetable crop to the agricultural sector in the economy of South Africa and it can be grown to maturity both on the field and under a controlled environment such as the greenhouse (Anonymous, 2016). Sprouting broccoli has many heads with many thin stalks. It has a head shaped like cauliflower but consists of tiny flower buds.

The temperatures of agricultural regions in South Africa do have daytime temperatures of between 10°C – 21°C, during the winter season, temperatures do not go below -7°C and at night temperatures are between 3-12°C, and sometimes even extreme day climates attain a maximum of 35 to 40°C in parts of the Gauteng, Free State, and 16°CNorth West and Northern Cape, (S.A Dept of Agriculture, 2015).

1.3: Broccoli Production

Broccoli is propagated in fields by direct seeding or using seedlings raised in nurseries. Broccoli is planted1.5cm deep in rows 10-15 cm apart, with 2 to 4 seeds per cm when raised in the nurseries. Planting in the nurseries is mostly used by vegetable producers, due to the higher operational efficiency, lower quantity of seeds, better plantlet standardization, easier handling at the field, improved pest and disease control, and earlier harvesting (Filgueira, 2003, Lopes et al., 2005, Laviola et al., 2006). In this system, the adoption of high-quality seeds is imperative, since the evidence shows that the low seed quality affects the vigor of the plantlets, reducing productivity (Andreoli et al., 2002; Kikuti&Marco Filho, 2007; Malone et al., 2008). In South Africa, the best time to grow the broccoli in the nurseries is starting from mid-January, February, and March and Transplanting must commence by April. The broccoli seeds are expected to grow in the nurseries for at least 4-6 weeks before transplanting to the fields. Nevertheless, broccoli can also be grown in early July and be transplanted within the months of August and mid-September. Broccoli requires 0.0164 to 0.1311 liters of water per week if normal rainfall is lacking to help ensure a high-quality broccoli crop. Broccoli requires more than average moisture, and when this is deficient it responds with poor appearance and slow growth. On the fields, it is expected to the planted with a spacing of 35-50cm. Broccoli is matured and ready for harvest in 10-16 weeks. The timing of harvest is quite vital depending on the species planted, for instance, spring broccoli should be harvested in the early morning because it wilts very fast when exposed to the sun.

The direct seeding planting method is seldom used in South Africa, due to some reasons such as the lack of controlling weeds effectively on bigger lands for commercial production and harsh climate,(Anonymous, 2017). According to Burpee, (2016), the benefits of adopting the direct seeding method in broccoli production is that it reduces labor and cost incurred if transplanting to bigger fields is involved. The lack of efficient herbicides in pre-emergence soil-applied weed control is a vital issue in South Africa. A crucial concern in broccoli production is the weed management technique to be employed because the physical features such as shortness in height do not support their competition alongside usual broad-leaved and annual weeds (Dillard, 2004). Weeds infestation in the field reduces the yield especially in the early growth stages; the crop-weed contest is more severe (Umeada, 2000). The conventional procedure of hand weeding is used in some farming regions however it is labor-intensive and time-wasting (Sandhu, 2003). No single herbicide has been proven to be efficient in the control of varieties of weeds, as the continuous application of the same herbicide leads to the weed species developing a strong resistance to that herbicide (Menalled, 2005).

1.4: Soil Applied Herbicides

The quantity and quality of broccoli harvested depend on good weed management. Several studies have demonstrated the competitive effect of weed on the vegetable crop. Broccoli yield was reduced by competition with Italian ryegrass (*Loliumperenne*) (Bell, 1995). Although important to the vegetable industry, only a few preemergence herbicides are registered and literature regarding the tolerance of vegetable crops to preemergence herbicides is limited (Bell, 2000). Soil-applied pre-emergence (PRE) and pre-plant incorporated (PPI) herbicides are very essential in broccoli production as they help combat and eliminate early-season weeds and residual long-season weed (Menalled, 2004).

Inadequate experience or knowledge insensitivity of broccoli tolerance to soil-applied herbicide may lead to weed control failure or crop damage or injury (Fabian, 2004). The pre-plant herbicides (s-metolachlor, trifluralin,) registered for vegetables in South Africa.

A few herbicides are registered for weed control in South Africa, such as Alachlor, which is primarily used for cabbage production (S.A Herbicide Guide, 2013).

Metolachlor herbicide showed success in the control of several weed species common with cole crops, kale and collard fields, also recommended for the control of both direct-seeded and transplanted cole crops, such as cabbage (Miller, 2005). It has previously been reported that Metolachlor herbicide did control weeds successively when applied either before or after transplanting, however, it was also noted that cole crops responses to metolachlor were contradictory. Belinder et al., (1990) reported a difference in the response of metolachlor herbicide applied after transplanting to two cabbage cultivars. Although no injury was recorded following pre-emergence application of Metolachlor in cabbage (Norsworthy,2006).

Halosulfuron applied before weed emergence provides good control of some broadleaf weeds. Masiunas (2002) reported that Halosulfuron (110 gai/ha) applied preemergence (PRE) provided more than 88% of redroot pigweed, velvetleaf, and common lambsquarters in pumpkins. Since Halosulfuron does not control grasses (Buker et al., 1998) it can be combined with a grass herbicide for broad-spectrum weed control (Bicksler&Masiunas 2005).

Thereare few reports available on the effectiveness of Clomazone, Oxadiazon, Metolachlor, and Halosulfuron on broccoli crop under Magelisburg humidity and thermoperiods in South Africa. Climatic and soil factors have different effects on herbicides activity (Torstensson, 2007) therefore it is essential to further study the effects of these factors on the bioactivity of Clomazone, Oxadiazon, Metolachlor, and Halosulfuron. A study was demonstrated to evaluate the sensitivity of soil-applied herbicides, Clomazone, Oxadiazon, Metolachlor, and Halosulfuron on direct-seeded spring broccoli hybrids under a simulated Magaliesburg humidity and thermoperiods in South Africa. This study was demonstrated by the author, using Magaliesburgthermoperiods replicated in a greenhouse at UNISA Science Campus. The results obtained on broccoli hybrids would help in suggesting appropriate weed management practices required to avoid any herbicide related problems.

1.5: Broccoli Demand in South Africa

The demand for broccoli in South Africa is gaining momentum even though the consumption of other cole crops is very large on a daily record. Broccoli is mostly sold in supermarkets in South Africa like Woolworths, Pick n Pay, and Checkers. There has not been so much statistical research for the demand for broccoli, but there is for other Brassica family crops like cabbage and cauliflower. Noakes, (2014) reports to balance the feeding pattern suggested that households can eat cauliflower. Statistics showed that cauliflower sales rose by 74% year on year to 220 tons in June 2015, which was matched by a 29.45% drop in the average selling price to R4, 489/t. (Department of Agriculture Forestry and Fisheries, 2014).

1.6: Problem Statement

Weed competition in broccoli production has been posing a great threat to broccoli commercial production in South Africa. Weed has been defined as any plant growing where it is not wanted (Anderson, 1996; Radosovich et al., 1997). Weaver, (1984) has shown that weed competition for even relatively short periods after transplanting, or crop emergence seriously reduces yields of cabbage.According toGovindra et al., (1983), the choice of an herbicide depends largely on the weed species to be controlled.

Herbicides availability for broccoli in South Africa is unique and the pricing as well because its constituents' component is dependent on the cost of importation and the quantity in which it is imported. These can also be the basis of debate and their wrongful use can give rise to considerable claims. Problems around bioaccumulation and the environmental impact of herbicides mean that they are subject to stringent regulation. Such issues have given rise to widespread doubts among the public and regulators alike where the use of chemicals such as organophosphate herbicides is concerned. These bureaucratic processes have made it a little difficult for farmers to get access to these herbicides for their broccoli farming, so they were left with the choice of planting without herbicides and thereby convinced that no need for herbicides.

Herbicides recommended for weed control on Cole crops may not provide complete control of weeds; thus, it is essential to grow Cole crops on the soil where the weed seed population is low (Zvalo&Respondek, 2007).

Velvetleaf (*Abutilon theophrasti*) can grow from 1 to 2.5 m in height and has numerous, wide broad leaves that compete for light, and it interferes with harvest operations and can reduce yields (Akey et al., 1990).

The importance of herbicides is gaining momentum because there have been so many issues associated with herbicides and Cole crop production. It has been argued that herbicides application has little or no significance on the yield of broccoli. Also, that no-till of the soil gives the same yield as a soil-applied with herbicide (Morse, 1995).

Also, it has been researched that there are always herbicide residuals in soil that are previously used for growing broccoli and as a result making that soil not suitable for planting immediately after harvesting so it is left for some time and that crop rotation is not economically satisfactory especially in a case of limited farmland.

The high cost of these herbicides and the residual effects has left some farmers to want to find a better way to continue with their no-till system of soil in the production of broccoli or to discover the best effective way of using a mixture of herbicides since it has been shown that using a single herbicide may not kill the weed at one application.

The recognized pre-plant herbicides registered for vegetables in South Africa are s-metolachlor, trifluralin, and these herbicides do not completely treat or control the popular season-long weed including common lamb's quarters (*Chenopodium album L*), common ragweed (*Ambrosia artemisiifolia L.*), and lady's thumb (*Polygonumpersicaria L.).*

A study was conducted in Ontario Canada to evaluate the effects of pre-plant herbicides on broccoli, cabbage, and cauliflower tolerance to oxyfluorfen (0.56 and 1.1kg/ha), dimethenamid-p (0.75 and 1.5kg/ha), sulfentrazone (0.1 and 0.2kg/ha), and a tank-mix of dimethenamid-p plus sulfentrazone (0.75+0.1 and 1.5+0.2kg/ha), representing once and twice the proposed use does for each herbicide/tank mix. Treatments included a non-treated weed-free control. Oxyfluorfen, dimethenamid-p, sulfentrazone, and dimethenamid-p plus sulfentrazone applied pre-transplant at the proposed and twice the proposed use dose in broccoli, cabbage, and cauliflower did not cause any visual injury and did not reduce the number of heads produced, head weight, or yield in all nine trials conducted. Based on these results, oxyfluorfen, dimethenamid-p, sulfentrazone, and dimethenamid-p plus sulfentrazone all have an acceptable level of crop safety for use at the proposed dose in broccoli, cabbage, and cauliflower (Sikkema et al.2007)

Vencil, (2002) reported that at initial stages, broccoli possesses a weak competing capacity among weeds primarily to its short stature, lack of branching, slow growth, and shallow root. Oxyflourfen applied PRE at 0.14, 0.28 and 0.56 kg/ha caused unacceptable delays in broccoli harvest and reduced stands and yields (Herbst&Derr, 1990a;1990b). Because cole crops are frequently direct seeded, the ability to apply oxyfluorfen PRE or POST would increase its utility. The application of applying oxyfluorfen has been recorded to result in high undesirable crop injury (Bhowmik&McGlew; 1986, Farnham & Harrison., 1997).

1.7: Theoretical Statement (Justification)

The residual effect of herbicides in the soil after planting and harvesting also coupled with the difficult means of obtaining herbicides approval, has led to a lack of official documentation on the effect or response of herbicides to vegetables in Magaliesburg magisterial area.

Herbicides used for broccoli provide both an economic and labor benefit. Rigorous infestation of weeds, particularly in the early stages of broccoli production, eventually accounts for a yield reduction of 40% (Behera &Singh., 1999). The conventional hand weeding or hoeing weeding technique is costly. The use of herbicides is a better option and their effective use in broccoli has been recorded by several farmworkers (Roberts et al., 1967; Putnam &Price, 1968; Whitwell &Senior, 1968; Anonymous., 1970).

Major problems in vegetables are caused by broadleaf weeds because grass weeds are much better managed in a rotation or they can be successfully eliminated with the use of selective foliar-applied herbicides.

In conventional no-till broccoli production, herbicides are commonly used to kill cover crops and create no-till mulch, and for follow-up post-emergent weed control. No-till agricultural technique has been regarded as successful because herbicides can control complete vegetation (Regnier& Emilie, 1990). Based on data in this paper and presented elsewhere (Infante&Morse, 1995; Serage, 1993), no-till broccoli can be successfully produced without using contact or preemergent herbicides. In these studies, various cultural weed-control methods were combined to minimize interspecific (weed-broccoli) competition. Each cultural method either promoted rapid broccoli growth and/or reduced germination and growth of weeds.

In research conducted by Morse, (2005), some results showed that no-till production of broccoli. These when properly established and maintained, are a viable option for producing broccoli (Hoyt et al., 1994). Pre-emergence herbicides and one post-emergence herbicide applied to transplanted cauliflower successively reduced the time required for hand weeding without affecting crop stand or yield (Stam &Ashley, 1980). In seeded cabbage and in transplanted broccoli pre-emergence herbicides reduced hand weeding without adverse effects on crop stand.

Herbicides applied as pre-emergence (Porwal&Singh. 2003) are reported that uncontrolled growth of weeds reduced curd yield of cauliflower significantly and the most critical stages of the crop-weed competition were 50 DAT. It is thus justifiable to conduct trials that test combinations of herbicides or sequential applications to check for effectiveness on weeds or crop sensitivity. This trial would help identify and recommend potential safe and acceptable soil-applied herbicides in broccoli production for registration under Act 36 of 1947 South Africa.

The author saw it desirable to demonstrate trials using four different herbicides to investigate the tolerance of broccoli to soil-applied herbicides. The herbicides Clomazone, Oxadiazon, Metolachlor, and Halosulfuron were trialed on broccoli hybrids by the author. It was discovered by the author that Halosulfuron is safe for use in broccoli production as a pre-emergent herbicide; as it provided an acceptable level of tolerance at 0.015. 0.025, 0.040, 0.055, and 0.07 $l.ha^{-1}$ application rates. Metolachlor and Clomazone herbicide caused a high unacceptable injury of more than 25% and Oxadiazon produced an acceptable injury and subsequently led to the death of the broccoli plant.

1.8: Overall aim

The overall aim of this research is to investigate the sensitivity of broccoli hybrid seedlings to selected soil-applied herbicides under simulated thermoperiods and humidity of Magaliesburg magisterial area.

Objectives

Objective 1: Toanalyze the effect of Clomazone (Isoxazolane herbicide) on broccoli (*Brassica oleracea* var. cymosa) hybrid seedlings under simulated Magaliesburg thermoperiods and humidity.

Objective 2: To investigate the sensitivity of broccoli (*Brassica oleracea* var. cymosa) hybrid seedlings to Oxadiazon (Ozadiozole herbicide) under simulated Magaliesburg thermoperiods and humidity.

Objective 3: To determine the influence of Metolachlor (Chloroacetamide herbicide) on broccoli (*Brassica oleracea* var. cymosa) hybrid seedlings under simulated Magaliesburg thermoperiods and humidity.

Objective 4: To determine the influence of Halosulfuron (Sulfonylurea herbicide) on broccoli (*Brassica oleracea* var. cymosa) hybrid seedlings under simulated Magaliesburg thermoperiods and humidity.

Objective 5: To conduct Gross Margin comparisons among the various Clomazone, Oxadiazon, Metolachlor and Halosulfuron herbicide treatments used in broccoli (*Brassica oleracea* var. cymosa) hybrid seedlings under simulated Magaliesburg thermoperiods and humidity.

1.9: RESEARCH HYPOTHESIS

Hypothesis 1: Clomazone (Isoxazolane herbicide) will have no effect on broccoli (*Brassica oleracea* var. cymosa) hybrid seedlings under simulated Magaliesburg thermoperiods and humidity.

Hypothesis 2: Broccoli (*Brassica oleracea* var. cymosa) hybrid seedlings will show no sensitivity to Oxadiazon (Oxadiazole herbicide) under simulated Magaliesburg thermoperiods and humidity.

Hypothesis 3: Metolachlor (Chloroacetamide herbicide) will have no influence on broccoli (*Brassica oleracea* var. cymosa) hybrid seedlings under simulated Magaliesburg thermoperiods and humidity.

Hypothesis 4: Halosulfuron (Sulfonylurea herbicide) will have no influence on broccoli (*Brassica oleracea* var. cymosa) hybrid seedlings under simulated Magaliesburg thermoperiods and humidity.

Hypothesis 5: There are no differences in gross margins among the various Clomazone, Oxadiazon, Metolachlor and Halosulfuron herbicide treatments used in broccoli (*Brassica oleracea* var. cymosa) hybrid seedlings under simulated Magaliesburg thermoperiods and humidity.

CHAPTER 2

2.0: LITERATURE REVIEW

2.1: Description And Origin Of Broccoli

Broccoli belongs to the “brassica” family, it is scientifically known as *Brassica oleracea L*. It is closely related to several culti groups of *B.oleracea L*. which are polyphyletic and it resembles so several other wild Brassica species (Snogerup et al., 1990). By some 8,000 years ago, cole crops plants of which broccoli belongs phylogenetically were grown for food alone by the people of China and Persia (De Can- dolle, 1885; Sturtevant, 1919). Sprouting broccoli, a genetically connected offspring of wild cabbage was trailed to some Coastal Europe, Low Countries, and England chalk cliffs. The plants were later taken to Persia after the Aryan invasion of Europe, from where they did spread all over the Mediterranean region. The name “broccoli ", as well as denoting a variety of Brassica which Pliny described in the time of Christ (Pliny, 1855), is applied to late cauliflowers. Gray, (1982) the development of broccoli and cauliflower is presumed to have occurred most likely in the east coast area in the Mediterranean basin. Furthermore, there have been so many resemblances existing between cauliflower and broccoli.

The foundational research results did show that the gene processes of reproduction are more in cauliflower than that of broccoli (Gray, 1982; Crisp &Gray, 1984; Gray, 1989). Several investigations that had been conducted to investigate the connection between broccoli and cauliflower had been conducted over recent years on the foundation of bio-morphological, anatomical, molecular, and molecular traits. Polymorphism hypothesis DNAof cauliflower indicates a possible broccoli linage and less likely linage to wild Brassica DNA (Song et al., 1988, 1990; Smith & King, 2000), but the latter hypothesis is in favor with the physiology of broccoli which looks more the same with wild Brassica species than those of the physiology of cauliflower (Nuez et al., 1999). Broccoli looks similar to cauliflower, but it belongs to another same species of a different cultivar.

Broccoli sometimes is referred to as a different variety of cauliflower, obvious in Britain, the name winter broccoli or heading is conventionally kept as biennial types.

In America, the annual green-sprouting broccoli type popularly known in Italy and Britain as Calabrese is called broccoli without qualification. The branching habit of broccoli has led to the term sprouting often used in referring to sprout broccoli and the edible young inflorescences commonly called sprouts. In broccoli, the head or sprouts (in sprouting types) are a bunch of fully differentiated flower buds, relatively few of which abort before flowering.

Broccoli is a cool-season annual crop that is also quite grown in spring or fall; in summer weather, it performs quite it does badly. Broccoli grows best when cultivated under a daily average temperature of between 18 and 23°C (64 and 74°F). An optimum temperature requirement of broccoli is in the range of 18-24°C (Tindall, 1992; Grevsen, 1998). The bunch of broccoli is green when the "head" of broccoli appears in the center of the plant. While the heading broccoli variety performs poorly in hot weather, mainly due to insect infestation, the sprouting variety is more resistant, though attention must be paid to sucking insects (such as aphids), caterpillars, and whiteflies.

Curd formation stage Maturity stage

Figure 2.1: Broccoli crop (Source:extension.udel.edu/weeklycropupdate/?tag=heat-stress)

Gauteng province popularly called the gold city has a very particular soil texture, climatic conditions, and majorly because it is quite rocky and so it is considered more as a tourist attraction province. According to South Africa Weather Services, (1998) it has an estimated annual rainfall of slightly above 700 mm on the Witwatersrand (approximately 1 700 ma. m. s. l.) and just over 600 mm north of the Magaliesburg (approximately 1 100 ma. m. s. l.) receives the lowest rainfall (0mm) in June and the highest (102mm) in January. Magaliesburg on average receives about 546mm to over 600mm of rain per year, with most rainfall occurring mainly during midsummer, Magaliesburg has enough annual rainfall required for broccoli planting. Magaliesburg soil is clay loam due to the weathering nature of heavy rocks which are the parent soil.

Broccoli can be grown on a wide range of soil types, from light sandy loams through to heavy clay loams. However, the soil must be well-drained, regardless of type. Drainage may have to be improved by raising beds, draining or scooping headlands to remove surplus water, and laying underground pipe drains. Loamy and clay loam soils are suited to late varieties because they are somewhat tolerant of poor drainage. Well-drained soils can be rotated frequently because clubroot is easier to control.

Broccoli requires soil temperatures as low as between 21°C-30°C for optimum growth and the monthly distribution of average daily maximum temperatures (center chart below Fig 2.2) shows that the average midday temperatures for Magaliesburg range from 17.3°C in June to 27.4°C in January. The region is the coldest during July when the mercury drops to 0.6°C on average during the night, according to www.saexplorer.co.za which makes Magaliesburg temperature also favorable for the growing of broccoli.

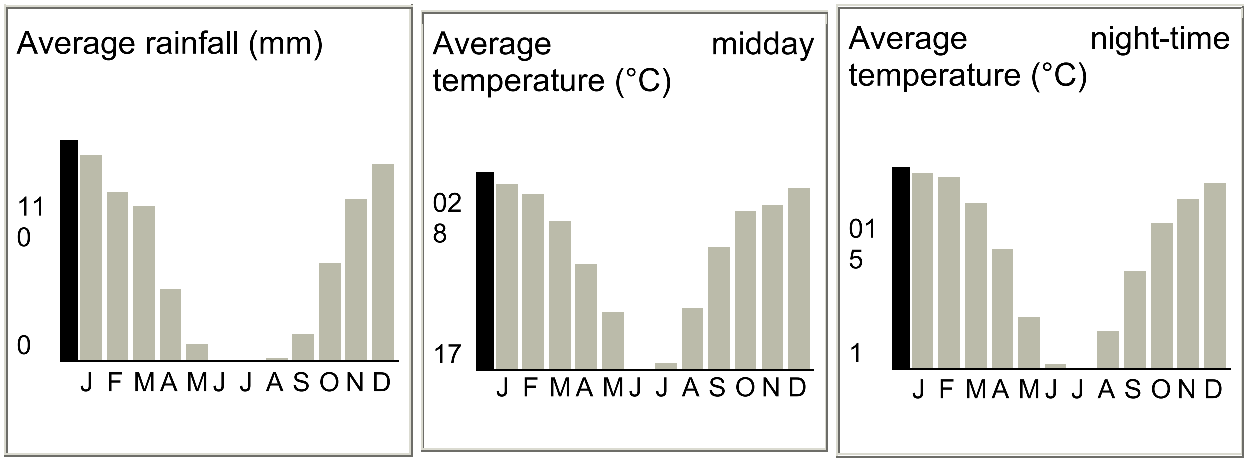

Figure 2.2:Monthly Average Rainfall And Temperatures Of Magaliesburg (Hauwaert, 2014)

Broccoli production as a leafy vegetable has been quite low because of the regular fight between weed and its crop and cover crops have shown to be a viable alternative for sustainable agriculture because of their contributions to soil fertility and improved crop performance. The contribution of cover crops to weed management is not clearly defined. Though, weed control could be improved if a manageable cover crop could replace an unmanageable weed population in the agroecosystem. Elimination of herbicides is not a good objective for using cover crops; rather, herbicides should be considered a tool for managing cover crops and optimizing their potential for improving soils and sustaining agricultural production. Weed control is especially important early in the season when weed competition can substantially reduce vigor, uniformity, and overall yield. This research will, therefore, be used to test the sensitivity of different herbicides class group mixtures to eliminate these weeds and eliminate any chances of its effects on the broccoli crop.

Figure 2.3 below depicts Magaliesburg South Africa thermoperiods, a broccoli growing region. Rainfall in July is quite at the lowest, with an average of 5 mm. While the highest rainfall is received in January the greatest amount of precipitation occurs in January, having over an average of 140 mm.

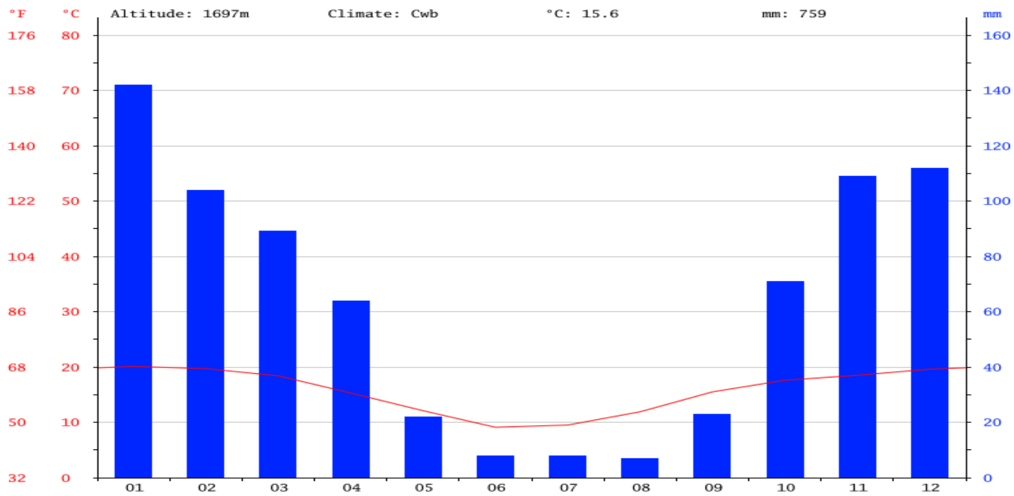

Figure 2.3: Magaliesburg Climate Graph (Hauwaert, 2014)

Magaliesburg with an average temperature of about 20°C and having the month of January as the month with the hottest temperature in the year, the region has the region experiences its lowest temperature within the month of June at a temperature of about 9.9°C and shows an increase towards the end of July (Fig 2.4).

	Jan	Feb	Mar	Apr	May	Jun	July	Aug	Sept	Oct	Nov	Dec
Avg. Temperature (°C)	20.1	19.7	18.4	15.3	12.1	9.1	9.5	11.9	15.5	17.6	18.5	19.6
Min. Temperature (°C)	14.2	13.9	12.3	8.9	4.8	1.5	1.9	4.1	7.9	10.8	12.3	13.5
Max. Temperature (°C)	26.1	25.5	24.5	21.7	19.5	16.8	17.2	19.8	23.2	24.5	24.8	25.7
Avg. Temperature (°F)	68.2	67.5	65.1	59.5	53.8	48.4	49.1	53.4	59.9	63.7	65.3	67.3
Min. Temperature (°F)	57.6	57.0	54.1	48.0	40.6	34.7	35.4	39.4	46.2	51.4	54.1	56.3
Max. Temperature (°F)	79.0	77.9	76.1	71.1	67.1	62.2	63.0	67.6	73.8	76.1	76.6	78.3
Precipitation / Rainfall (mm)	142	104	89	64	22	8	8	7	23	71	109	112

Figure 2.4: MagaliesburgAnnual Climate Graph (Hauwaert, 2014)

There is a difference of 135 mm of precipitation between the driest and wettest months. The average temperatures vary during the year by 11.0°C.

2.2: Weed Management Methods In Broccoli

Weed management has been an integral aspect of crop cultivation and it has become a very important aspect of vegetable production. Weeds lower productivity and quality of agricultural products. Weed control practices can be expensive (Sinden et al., 2005), especially when infestations are huge and weed control is delayed (Harris & Timmins, 2009). Weed management has various methods which include agronomic, mechanical, cultural, physical, biological, and chemical (Qasem, 1992), each may be used alone, or all are usually integrated for any successful weed control program (Qasem, 2003; Singh et al., 2006). Without herbicides, the yield can be reduced (Bell, 2000), or hand weeding expenses may increase (Prather, 1996). Vegetables are quite small, but it produces high–value crops that are commercially appreciated. Weeds have become a great challenge for Broccoli commercial farmers. Weeds do compete with the crop for nutrients which directly leads to a reduction in harvest and often leads to delay in maturity. More all so, weeds provide a good breeding environment for insects, plant diseases, and nematodes and can reduce the effect of spray-applied pest control materials by interfering with pesticide deposition (Lanini et al., 2002). Moreso it is important to note that weed control practices are jointly used with other farm operations for efficient crop production. Herbicides are a chemical that inhibits or kills weeds, which do not harm crops if properly handled and selectively used. They can be either organic or inorganic (contain no carbon) chemicals (California Weed Conference, 1985) and can be easily designated from botanical or mico-herbicides (Rice, 1983, Mo & He, 2005). Herbicides are available to use on a broccoli crop. A good number of shallow cultivations are an essential part of a weed control program. Efficient weed control requires the integration of cultural and chemical methods. Broccoli should be planted on land free of perennial weeds (Jon et al., 1995), where the annual weed seed population has been reduced by cultural practices such as crop rotation, stale seedbed, or hoeing. In South Africa, the summer broadleaf weeds are most frequent.

2.2.1: Agronomic Weeding Method.

This method involves the old unconventional systems such as plowing, which allows for tillage of the soil in which both the weeds and its seeds are buried in the ground to make it difficult to germinate, this process has actually been shown to fail in the short run, because on the long run the weed seeds would be uprooted in the next turn of tillage (Deng Wei et al., 2010). Another is the crop rotation and alternate husbandry, which has also been shown to fail because it does produce some kind of unstable soil environment as it entails so much work in selecting types of rotational crops and arranges a reasonable cultivating sequence (Deng Wei et al., 2010). A third type is the breeding of new crop varieties, whereby crop varieties with rapid crop growth, vigorous seedling growth, and larger leaf area can inhibit the growth of weeds. Rational close planting, intercropping, and narrow-row sowing can also help with weed suppression.

2.2.2: Mechanical Or Hand Weeding Method

Mechanical weed control has been considered quite a labor and capital intensive, especially in developing countries and countries not sophisticated in mechanized Agricultural practices. There are various kinds of mechanical weed control such as hand weeding which is highly labor-intensive, difficult, time-consuming, and inefficient. Another is the brush weeding method which pulls out and buries weeds in between crop lines and inner-rows, considered better in wet weather in achieving high weed control, common types are vertically rotating cylinder brush and the horizontally rotating disc-brush type (Deng Wei et al., 2010). Also, we have the harrow weed control which is widely used in non-chemical weed control at pre and post-emergence stage of weed seedlings, it is relatively low cost-effective, although it has been argued that harrowing is not necessary if there are few weeds after sowing, because harrowing not only has no effects on weed control but also may cause damage to crop (Turner, 2006). Moreso it is important to mention that all mechanical weed control methods are very likely to result in severe damage to soil structure, causing severe loss in soil structure and soil erosion by the wind so, therefore, mechanical weed control methods should be used cautiously in places where water resources are scarce. In a bid to reduce environmental pollution and improve the quality and safety of agricultural products, adequate emphasis should be laid on the study of non-chemical weed control technologies and methods to adapt them to the developing trend of green and healthy agriculture. In some local areas in South Africa, weeding is done a few days or weeks before planting while in some other situations weeding is done within two or three weeks after transplanting (Tu, 2001), the problem with this is that sometimes the farmers delay this weeding for a longer period and this results to loss of crop as competition would have increased between the weed and the crop. Mechanical weeding must be conducted before the planting of broccoli and must be continued periodically after planting until at least the curd formation stage to eliminate the weed competitive levels of the crop at maturity especially by attacking the roots (Randall, 2001).

2.2.3: Cultural Weeding Methods In Broccoli Production.

Cultural weed controls the use of a non-chemical process in weed crop management operations; this involves all processes from land selection, preparation of the land, all through crop harvest and post-harvesting (Zaragoza, 2001). According to Fageria, (2003) the selection of planting date, numbers of seeding, row spacing, fertility, irrigation, and adapted seed varieties to enable the crops to grow strongly. This method plays a vital role in weed management hence it consists of mechanical, manual, and cultural control methods.

2.2.4: Chemical Weeding Methods in Broccoli

In Broccoli production, proper weed management practices are of paramount importance for not compromising yield (Sonnerberg & Silva, 2005), crop management and harvesting, and especially the quality of the commercial product more especially during the early developmental stages, because as the plants grow slowly they become more prone to be suppressed by weeds (Tu, 2001). Present-day mechanized farming cannot afford the luxury of so much cost on using so much manpower in weed management and increasing cost to production and waste of time, therefore chemical method on large cropped areas is more economically viable and due to its larger practicality, it has been used by farmers for some time now. In most developing countries, the practice of chemical weed control is not generally accepted, because cheap labor is rather more affordable, the lack of technical knowledge from extension workers and some times the high cost of the chemicals and very important is the knowledge involved in herbicides application because the wrong use of these chemicals most times leads to death of crops and causes crop injury (Su, 2006), herbicides selective failure and weed operation control, air and soil pollution and options limitation in crop rotation. Some identified factors are the reasons for herbicide failure under field environment, though these are usually due to human errors in wrong application techniques (Ross & Lembi, 1999). A wrong diagnosis in weed management, bad weather conditions for weed control chemicals are also some causes for herbicide failure (Gwynne & Murray, 1985). However, few chemicals have been registered for weed control in Broccoli in South Africa because some chemicals have adverse effects on consumption due to their chemical composition and constituencies. It is also worthy of mentioning that some of these chemicals have demonstrated a very good early-stage weed control. Thus, it is important to select what molecules are considered suitable to control the weeds and not affect the broccoli crop (Reis et al., 2014). The number of herbicides available to vegetable growers may be further reduced shortly (Bell et al., 2000).

2.3: Factors Affecting Selectivity AndEffectiveness Of Herbicides

The usage of herbicides in weed control management often generates a level of public concern and receives some sorts criticisms, most recently, some environmentalists and nature conservers disagree with some pesticide usage, they rather suggest other options for weed management mechanisms or ecological friendly chemicals, while man-made herbicides are still easily accessible, and preferred in weed management and heavily used in both developing and developed nations. Though, 44% of the world's pesticides are herbicides of which the USA has 57% of such pesticides (Kiely et al., 2004).

Most of the factors that influence herbicide activity include the application technique, herbicide formulation, crop factors, application rate, environmental conditions, weed species, and the time of application of herbicides (Bruin, 2007). Though weeds are very diverse in their competitive characteristics and nature, they explain also the amount of loss of yield and other harmful effects on crops caused by weeds, hence the need for control and proper time application is required (Zimdahl, 1980). Each label on herbicides informs all necessary legality and warranty of the (Massey, 2006). Sometimes, the soil conditions, weather conditions, weed species, and developmental stage of development do affect the efficacy of herbicide applications of which the farmer is usually more knowledgeable than the producer of the herbicide. The manufacturing company offers certain guarantees and compensation for any crop injury caused provided the farmer uses the indicated dosage properly (Massey, 2006). Manufacturers and producers of herbicides make the label rates for the efficacy of some conditions differ from the standard for a reason (Massey, 2006). Although, generally weeds of similar requirements and growth habits to crop plants they attack are known to be more destructive and cause greater yield loss and higher damage to crop plants than weeds of different requirements or morphology (Ross &Lembi, 1999). In addition, improper weed problem analysis, wrong herbicide selection, and poor weather conditions in chemical weed management are reasons for some herbicides failures in controlling weeds (Gwynne & Murray, 1985).

2.3.1: Crop Factors

The uniqueness of crop species varieties is prevalent in their sensitivity, selectivity, and responses to herbicides. These variations have been also reported between different crop cultivars in response to the same or different herbicides (Duwayri&Saghir, 1983; Felix et al., 2007; Abit et al., 2009; Kong et al., 2009 &Jin et al., 2010). In addition, cultivars are diverse in emergence, germination, duration and growth development, biochemical and physiological responses (Grime, 1986). Such characteristics significantly influence herbicides efficacy, plant performance, and subsequently herbicides physical, biochemical and physiological, degradation. The anatomy, succulence, anatomy, physiology, and morphology of crop seedlings are the factors that determine the extent of herbicide efficacy and crop injuries and damages. Crop plants' sensitivity to herbicides helps determine the herbicide selectivity and its safe uses. Crop plants with so much similarity with weeds are vulnerable to herbicides very early at the growth stage and that stage is where crop injury is very high and easily noticed. Moreover, it is sometimes acknowledged that crop plants grown from seeds are more vulnerable to herbicides when compared to those from transplants and therefore, herbicide sensitive crops are suggested to be grown from seedlings instead of seeds in situations where soil-applied herbicides are used.

Foliage-applied herbicides are well efficient against weeds at early stages mostly (1-5 leaf) growth stages even though the crop seedlings show the level of a significant symptom of injury at this stage which could recover, otherwise a more selective and safer herbicide must be administered. Although this depends on the rate and time of the herbicide application (Friesen, 1967; Friesen et al., 1968; Carter et al., 2007) and existing environmental conditions (Coupland, 1987). Herbicide selectivity is highly dependent on crop internal factors as well as climatic conditions that is activated or inactivated herbicide molecules. Above ground morphology differs incrops; while some are broad-leaved others are narrow-leaved. This is equally so for weeds leaf arrangements on the stem and their display are also different for varying crop species, in addition to differences in morphology heights and size. All these do affect herbicide spray retention on crops vegetative parts, herbicide safe use, and selectivity on these crops. These factors could affect herbicide sensitivity or tolerance of crop plants.

2.3.2: Environmental Factors

Environmental conditions before, during, and after application influence herbicide coverage on the plant or soil surface. The efficacy of herbicide may vary depending on the environmental conditions. The first five hours of the day during summer, the suitable summer, conditions are generally relatively high humidity, reduced temperatures, and low light intensity, but quite a different afternoon (Cieslik et al., 2013). Very high temperatures favor PROTOX inhibitors' activity (Li et al., 2000; Fausey& Renner, 2001; Price et al., 2004; Hatterman-Valenti et al., 2011). For instance, at a high temperature, the herbicide fluthiacet was three times and twice more efficient to control *C. album* and *A. retroflexus*, respectively, when compared to the results obtained at 10°C (Fausey & Renner, 2001). Likewise, the control of *Ipomoea lacunosa* was greater when acifluorfen was applied at temperatures of 35/26°C (day/night), compared to temperatures of 27/18°C (Oliver & Lee, 1982). Improved herbicide efficacy as a result of temperature increase could be detrimental to a crop because it tends to reduce herbicide selectivity. A greater action of flumioxazin occurred in *Arachishypogaea* seedlings when the temperature rose from 15 to 25°C (Price et al., 2004). Similarly, an increase in temperature from 15 to 34°C resulted in a reduced plant height of soybean crops treated with sulfentrazone (Li et al., 2000).

Another reason herbicidal activity is being enhanced by temperature enhances is that temperature has a direct relationship with the chemical reaction rate of the herbicide constituent molecule or active ingredients. Subsequently, plant growth, photosynthesis, plant development, and plant metabolism are dependent on temperature. Evapotranspiration is also controlled by temperature; hence it affects the water condition of the plants, mineral absorption, and cuticle hydration (Zanatta et al., 2008). When temperatures are high, the flow of herbicide absorption is favored due to reduced viscosity of the cuticle waxes and increased rate of herbicide diffusion through the cuticle. High temperatures together with a high relative humidity level, there is strong hydration of the cuticle, which also supports the absorption and the efficacy of PROTOX inhibitors (Price, 1983). Crop plants of winter species, *B.oleracea* were less sensitive to oxyfluorfen at a temperature of 20 to 25°C, when compared to temperatures of 10 to 15°C (Harrison & Peterson, 1999).

Light intensity has effects on the efficacy of herbicides. It was discovered that high light intensity favors the efficacy of PROTOX inhibitors (Fausey& Renner, 2001; Hwang et al., 2004; Camargo et al., 2012). The weed control by PROTOX inhibitors is favored in the presence of light due to the herbicide mode of action. At low light conditions, the numbers of free radicals produced are reduced and decrease the harmful effects of PROTOX inhibitors on plants (Krämer&Schirmer, 2007). Also keeping plants in the shade before the herbicide application favors the action of PROTOX inhibitors (Thompson & Nissen, 2002). For instance, some soybean plants that were placed in an environment with 80% shade for five days before the application of sulfentrazone showed up to 40% more injury than those exposed to 100% irradiation. In addition, maize plants that were placed in an environment with 80% shading showed 9% more injury compared to a situation without shading (Hatterman-Valenti et al., 2011).

Rainfall is essential for the soil-applied or pre-emergence herbicides movement into the soil and activation (Rao, 2002). It creates the leaves' abilities in a water-soluble relationship which helps reduce losses in a situation where rain falls almost immediately after herbicide application (Hartzler, 1997). Relative humidity also influences herbicide performance. The weed control of *Xanthium strumarium* and *Ambrosia artemisiifolia* with acifluorfen was 30% higher when it was applied on plants at a relative humidity of 85% compared to the condition of 50% relative humidity (Ritter & Coble, 1981). Herbicides acifluorfen, fomesafen, and lactofen sprayed on plants of *Sidaspinosa*, *Ipomoea lacunosa*, *X. strumarium*, and *Ipomoea hederaceae* var. *integriuscula Gray* showed better efficacy when the weeds were at 85% relative humidity compared to the condition of 50% relative humidity (Wichert et al., 1992). The justification to why increased relative humidity favors the efficacy of PROTOX inhibitorsinclude: high hydration of the cuticle because it favors herbicide absorption; and high plant metabolic activity, as it favors the translocation of the compounds. Certainly, the translocation of acifluorfen in *Crotalariaspectabilis* increased fourfold when the relative humidity increased from 40 to 100% (Wills &Mcwhorter, 1981). On the contrary, water stress decreased the absorption of acifluorfen, for instance. Water stress caused by the drastic reduction in soil moisture increases the thickness of the leaf cuticle, as a way to prevent water loss by the plant. The cuticle of plants cuticle under water stress was 50-80%thicker when compared to occasions where there was adequate soil moisture (Hatterman-Valenti et al., 2011).

2.3.3: Soil Factors

Various soil factors such as soil pH, soil microbes, soil moisture, soil texture, soil organic matter, and soil temperature, helps improve the herbicide activity in the soil, in the hierarchy of most important form these factors, looking at all factors, clay content and soil organic matter are the most vital soil factors that indirectly affect all the processes influencing herbicide activity (Reinhardt &Nel 1984; Vasilakoglou et al., 2000; Liu et al., 2005). The heavier the soil, the faster the pore spaces get full and run-off commences (Menalled& Dyer 2005; Hartzler, 1997). Also, the higher the clay content and organic matter the higher the adsorption of the herbicide to the soil particles resulting in a decreased bioactivity (Day et al., 1968; Koskinen & Harper, 1987). Penetration of herbicides into soil particles takes place through numerous methods depending on both herbicide characteristics and the soil type (Rao, 2000).

Herbicide activity is high in fine-textured soils (Liu, 1999), the possibility of crop injury is higher on coarse-textured soils low in organic matter in higher, because there is the availability of a higher amount of applied herbicide for the plant uptake (Weller, 2002). Rao, (2000) reported that herbicide purification is influenced by soil pH influences by upsetting the ionic or molecular character of the chemical that is the ionic character and the cation exchange capacity (CEC) of the soil colloids together as the soil microorganisms activity.

Soil pH has an influence on herbicides persistence activity in the soil, mostly at a pH range of 4.5 or below and 7.5 or above (Monaco et al., 2002). Soil pH can change herbicide ionic molecule nature, which affects the rate of adsorption, solubility, and rate of herbicide breakdown. Variations in the soil pH affect its ability to absorb and retain herbicide molecules, thereby affecting the leaching of the herbicide through the soil profile. Also, a variety of herbicides responds differently to changes in soil pH. Liu et al., (2005) recorded that the highest degradation of acetochlor took place under strongly alkaline conditions (pH =12) and was lower under acidic conditions (pH < 5). Moreover; microbial degradation of the herbicide is being influenced by soil pH as it influences the microbial life within the soil. The numbers of Microbes are more likely to increase in soils with a neutral pH, resulting in a faster loss of activity in these soils due to a higher microbial activity (Rao, 2000). In as much as herbicide is broken down, its population numbers normally return to the numbers initially before the herbicide application, while there is a noticeable increase in microbial populations. A change in soil pH continues reducing microbial populations until a neutral pH is achieved (Monaco et al., 2002).

The product received from the influence of soil temperature on herbicides relates to the rate of chemical degradation through hydrolysis as well as the activity and population of soil microbes (Rao, 2000; Hembree, 2004).

Temperature helps control the soil-applied herbicide's activity majorly so due to its effect on the rate of emergence, growth, and seed germination (Brucher, 1997). The degradation of propachlor, alachlor, and metolachlor, were found to increase with an increase in temperature to 30°C (Zimdahl& Clark, 1982). Likewise, herbicide degradation was improved in non-sterile soils when compared with sterile soils as soil temperature increased from 15 to 30°C (Jeffrey et al., 2003). Herbicide persistence in the soil is also affected by soil temperature. The lower the soil temperature the lower the microbial activity thus the longer the time the herbicide will stay active in the soil (Kulshrestha& Singh, 1992; Gestel et al., 2007). Soils with lower temperatures most times contribute to herbicide activity by delaying seedling growth and germination. Thus, results in plant emergence delay and increases the time needed for plants to reach the one leaf stage. New emerging plants are more vulnerable to soil-applied herbicides under cool conditions when compared to under warm temperatures because plant emergence is delayed and metabolism is slowed (Baer, 1999). An intense high temperature frequently produces crop injury easily exposing the crop to severe stress. Herbicide vapor pressure depends to a large extent on temperature. Hence, an increase in temperature leads to an increase in the volatility of the plant or soil it comes in contact with (Torstensson, 2007). Immediately the soil active sites get filled with the herbicide, there’s a possibility that the vapor density of that herbicide above the soil becomes equivalent to that of the pure active compound of the herbicide (Belles & Nissen, 2006). Though a smaller application rate the temperature has no more influence on the vapor pressure, however, it becomes affected directly by the energy of sorption to the soil environment thereby exhibiting a less effective trend (Belles & Nissen, 2006).

Microbial decomposition is one of the crucial methods by which herbicides are decomposed in the soil. This is a process in which the herbicide is broken down by microorganisms living in the soil. The organic herbicides are consumed by either aerobic or anaerobic means by these microorganisms in the soil (Chakrabarti et al., 2006). This happens when microorganisms such as fungi and bacteria use the herbicide molecule as a food source, they utilize them as a source of energy and nutrients for growth and reproduction. Factors that are favorable to microbial growth include favorable soil pH levels, fertile soils, warm temperatures, oxygen, and adequate soil moisture, (Rao, 2000). Adsorbed herbicides are more slowly degraded because they are less available to other microorganisms (Hembree, 2004; Menalled& Dyer, 2005; Daniel et al., 2005).

Soil moisture helps the rate of herbicide adsorption to the soils. Herbicide uptake and phytotoxicity are incredibly reliant on soil moisture, which is important for herbicide movement, particularly when the herbicide is moving through mass flow (Rao, 2000). The amount of moisture in the soil affects the quantity of the herbicide particles that can be accepted by the soil, as these molecules tend to compete with water molecules for assimilation sites on the mineral colloids. When the conditions are dry, plants are thus less likely to absorb toxic concentrations of herbicide (Rao, 2000; Carolyn, 2007). But when soil moisture is replenished, the herbicide will then withdraw from the colloids and re-enter the soil solution. In dry soil conditions, herbicide activity is highest while it is relatively the lowest when in most soils. As a result, weed management is generally better under a moist soil situation because it would be readily absorbed by the plant. (Taylor-Lovell, 2002). Consequently, an abundance of wetness from intense rainfall can result in the leaching of herbicides or excess quantity of the herbicide to the germinating crop site to cause damage to the crop. Some herbicides such as acetochlor, show high sensitivity on emerging seedlings, even though it doesn't require translocation to the leaves to establish their effectiveness. However, herbicides surely do rely on soil moisture to perform, because without wetness or moisture good seeds cannot germinate. (Cooper, 1996).

The readily translocated herbicides in the xylem becomes active in the leaves (photosynthesis and pigment inhibitors) and may control established weeds, or injure the crop, shortly after rainfall events due to the release of herbicide into the soil solution from where they can be absorbed by plants (Carolyn, 2007). This coincides with what Green &Obien, (1969) suggested, in that herbicide, phytotoxicity would increase with increasing soil water content. Allemann, (1993) discovered that alachlor phytotoxicity to sunflower was increased with a decrease in soil moisture.

The soil organic matter is one of the most imperative soil properties which influence herbicide activity (Weber & Peter, 1982; Liu et al., 2002; Rao, 2000). However, in South Africa, this is possibly not the case as most soils have an organic matter content of <1% (Reinhardt & Nel, 1984; Bayer, 2002). Organic matter has been reported to have a greater adsorption capacity (Weber & Peter, 1982; Reinhardt & Nel, 1990; Vasilakoglou et al., 2000). Also, the organic matter content of the soil will, therefore, play an important role in determining the mobility of an herbicide in the soil. The soils that are low in organic matter content that have a high sand fraction have the greatest potential for herbicide leaching (Rao, 2000). However, the organic matter content of most South African soils is <1%, and Reinhardt & Nel (1984; 1989) showed that the organic matter content of the soil is the best analyst of alachlor activity. These results were also confirmed by Allemann(1993) who demonstrated that an increase in soil organic matter content of 0.12% C was enough to reverse the bioactivity of four times the recommended application rate of alachlor on sunflower.

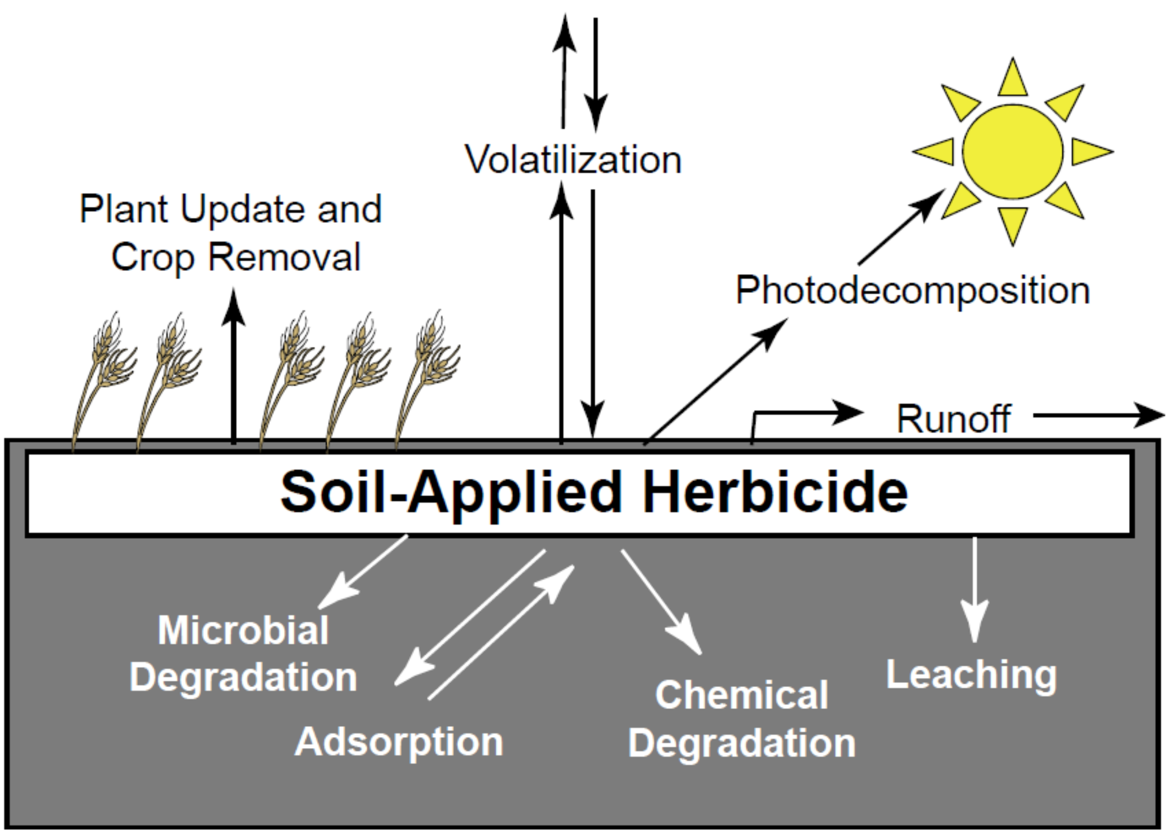

Figure 2.5: Factors affecting soil-applied herbicides (Menalled, 2004).

2.4: Spray Water Quality

Good and hygienic water is an important factor in herbicide activity (Montana State University Extension, 2013). Johnson, (2002) reported that the quality of water for herbicide usage must always be clean and free from any impurities, as any impurities can affect the effectiveness of the herbicide by attacking the bonds of the molecules and deactivating the chemical bond of the herbicide. Also, Beard, (2001) stated that any water with impurities such as clay or sand found in the water, such as sand or clay elements can cause blockages on the nozzles and damage spraying pumps.

2.5: Herbicide Application Time.

The accurate timing for herbicides application is vital in evaluating the effectiveness and duration length of weed control (Carter et al., 2007; James et al., 2007) when herbicides are applied at pre-planting in crops grown from seedlings such as in the case for most vegetables; pre-sowing as in the case of seed-sown grain field crops and some vegetables such as many cucurbits; and as postemergence. Soil-applied herbicides do control germinated seeds or weed seedlings either by contact or systemic action, prevent weed seed germination or seedlings growth and thus prevent early weed competition and protect crops from planting or sowing date until a good canopy is formed. This is the most vulnerable phase in the entire life cycle of most crops to weed competition. However, in all cases, crop tolerance and herbicide selectivity are essential factors.

Herbicides can be applied to the soil before the emergence of crops and weeds and they could also be applied to the foliage after emergence (Massey, 2006). This is represented in Figure 2.6 below (Menalled, 2004)

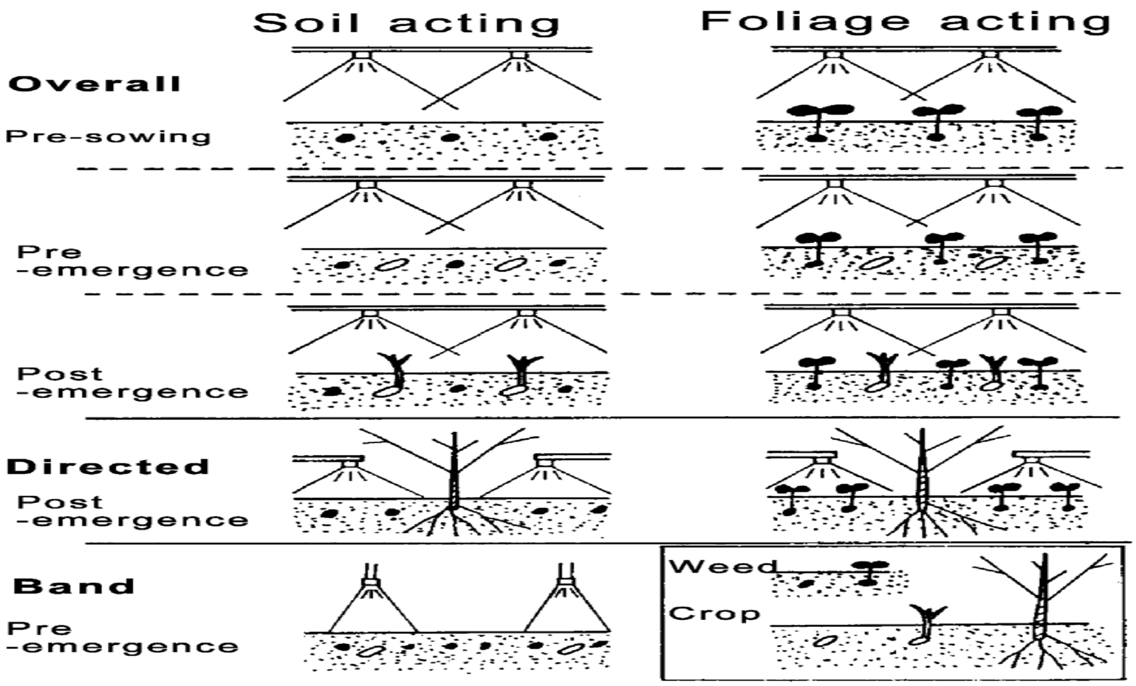

Figure 2.6: Diagramatic Illustrations in Foliage and Soil Patterns of Sprays (Menalled, 2004).

Herbicides do not avoid weed-seed germination; rather, they are first absorbed by the root or shoot of the seedling and then give their phytotoxic action (Taylor, 2001). The efficacy of soil-applied herbicide depends on herbicide accessibility for uptake by the germinating weed seedling (Qasem, 2007).

The soil-applied herbicide is absorbed into the germinating weed seedling to enable adequate weed control (Muller, et al., 2015). This normally takes place before the seedling emerges from the soil. The majority of the early soil-applied herbicides applications in no-till systems try to increase the chances that so much rainfall will be received before planting to incorporate the herbicide (Dhiman, 2005). In an occurrence that no rainfall is received between application and planting, mechanical incorporation, where appropriate, will in most cases adequately transport the herbicide into the soil solution. Usually, annual crops are generally more vulnerable to herbicides when in the seedling stage compared to when they are at a complex stage. The higher the advanced stage a crop attains, the thicker their wax layers on leaf surfaces becomes thereby reducing the absorption of herbicide (Colquhoun, 2006).

Precipitation offers appreciable uniformity in the incorporation of herbicides, whilst incorporation manually reduces entirely the dependence of regulated or expected rainfall or irrigation. Using the wrong equipment or wrong adjustment in applying the herbicide to wet soil often leads to poor results in the effectiveness of the herbicide in controlling the weeds. According to Weber, (2000) herbicide incorporation should be performed with two perpendicular passes, 24 hours after application if excellent results is to be achieved. If the land has more than 40 to 50 % crop residue cover, it may be necessary to plough it before herbicide application and incorporation. Herbicides are applied at pre-planting in crops grown from seedlings such as of most vegetables; pre-sowing in case of seed-sown grain field crops and some vegetables such as many cucurbits; and as post-emergence (Colquhoun, 2006). Following the label instructions such as incorporation depth, equipment adjustment requirement for the soil,pre-plant tillage, and crop residue, is very important. Talbert, (2000) reported that the efficiency of soil-applied herbicides is dependent on so many factors no matter the state of the soil. Herbicide time application is very vital because the length and efficacy of weed control time in necessary in herbicide selectivity (Qasem, 2011).

(i) Pre-Plant Incorporated: These are the herbicides that are introduced into the soil before the crop is sown into the soil (Wilson, 2002) and before weeds emerge. The herbicides are often incorporated because they are most volatile, light, and unstable, so if not applied incorporated the active ingredients could be lost and degraded if they remain on the soil surface.

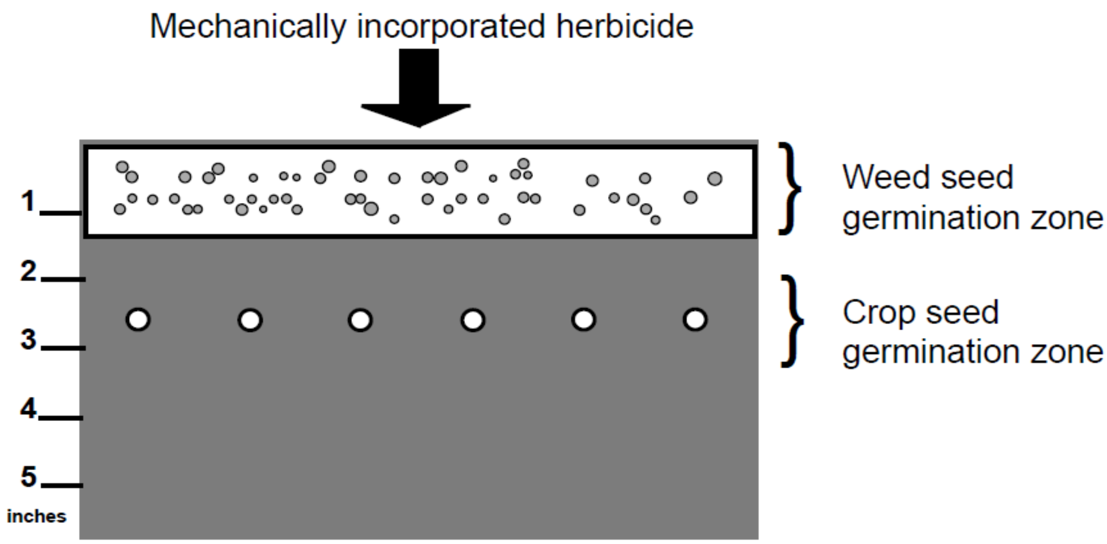

Figure 2.7: IncorporatedSoil-applied herbicides should be done in the weed germination zone for close contact with weed seeds to be established and not the crop seeds (Menalled, 2004).

(ii) Pre-emergence: Pre-emergence herbicides are applied before the emergence of weeds; this entails before crop emergence as well. Herbicides that have higher toxicity on the emerging crop seedlings are applied before the crop is planted (Dyer, 2004). Such molecules have some solubility in water and become assessable for the germinating weeds which are taken underground by the roots or hypocotyls of the weed, and quite a huge amount may be leached away from the main purpose.

(iii) Post-emergence: These are herbicides that are applied after the emergence of the weeds (and usually, but not necessarily, the crop as well) (Klein, 2002). Most post-applied herbicides are only active through the foliage, while some others are absorbed through the roots. For instance, auxin and Bentazon are absorbed through the foliage. Post-emergence herbicides can be applied to the entire crop or weed canopy. This is often described as an over-the-top application (Martin, 2002).

2.6: Herbicide Formulations

Herbicide formulations are in various forms which include, water-soluble liquids which require wetting agents to work properly, water-soluble powders which entail thorough stirring or agitation in preparation before usage, water emulsions , these involve some agitation and held together by an emulsifier, wettable powders require continuous agitation and mostly used on soil, water dispersal liquids , water dispersed granules , granules these need water to leach them down into the soil, and granular form often utilized in spot treatments such as Tebuthiuron (Kortekamp et al., 2011). Regarding its mode of action, herbicide formulation influence selectivity and thus enhances crop growth. Generally, used herbicide formulations are aqueous and granules. Because these formulations require certain types of equipment to apply, such as spreaders or sprayers respectively. Even though, both forms need to be uniformly applied with the second most used in horticultural crops and are least selective. It is important to note that forms such as powders (dust), granules, ester forms are less stable than others while water-soluble forms are more stable than emulsions (Kortekampet al., 2011). An aspect of herbicide formulation is found on the label, which indicates the active ingredients, time of herbicide application, common name, the herbicide selectivity, formulation, volume of spray solution or carrier required per unit area, persistence (residual) method of application, rate of application, post-application treatments, (Felix et al., 2007), weed species affected, and crops in which the herbicide is recommended, weed control spectrum and tolerant weeds, volatility and conditions under which the herbicide is selectively used and any possible crop injuries and precautions. This information is of great importance for the farmer and must be consulted and strictly adhered to if a successful weed control operation is the ultimate farmers' desire. However, the actual herbicide selection solely relies on the weed species in that specific planting region or area, and affected by environmental factors, some herbicides differ in their potential for damaging crop plants at certain levels of development (Williams et al., 2003). According to Van Zyl, (2011) the following herbicides were registered for cruciferous crops in 1998; Chlorthal-dimethyl, Oxyfluorfen, Alachlorand Metazachlor. Chlorthal-dimethyl in South Africa is sold as Dacthal W-75 (Van Zyl, 2011), it is administered within 24 hours of transplanting to a weed-free and wet soil surface on Brussels sprouts, cabbages, and cauliflower except for broccoli.

In South Africa, the herbicide Metazachlor is sold as both Precede and as Butisan (Van Zyl, 2011), must be applied before emergence of. It controls mostly annual grasses but also has effects on specific broadleaf weeds too. In an ideal situation, it controls yellow nutsedge. It is a registered herbicide in broccoli and cabbage weed management, even though it has been shown to cause some level of injuries on cauliflowers crops. Similarly, Oxyfluorfen herbicide is sold as Goal and as Galligan 240 (Van Zyl, 2011) and is recognized for use in several cole crops. Goal herbicide is effective in the control of annual broadleaf weeds and certain grasses and must be applied to a well-prepared soil surface (Dow AgroSciences, 2012). Goal works effectively on transplanted crops which must be immediately irrigated after transplanting. Moreover, when the situation is under cooler weather conditions, where inversions occur, some crop damage may result in young transplants. The researcher used specifically the parameters below since the evaluation of soil-applied herbicides on broccoli hybrids was assessed from the germination stage of broccoli up to three weeks of the seedling stage (≤21 DAP). Also,soil-applied herbicides whose activity is observable in seedlings of broccoli as the critical period for determining the effectiveness of soil-applied herbicides. The shoot and root growth parameters listed below are measurable at the seedling stage of broccoli, this agrees with a finding by Wagner, (2006), who stated the parameters are measurable at the seedling stage.

2.7: Plant Shoot And Root Growth Parameters Influenced By Herbicides

Table 2.1: The Measured Response Of Plant Shoot And Root Growth Parameters

No	PARAMETER	GROUP
1	Germination Percentage	Germination parameter
2	Plant height	Stem parameter
3	Root Length	Root Parameter
4	Leaf Injury	Leaf Parameter
5	Stunt Count Percentage	Stem Parameter
6	Necrosis Percentage	Growth Parameter
7	Emergence Percentage	Germination parameter
8	Days to Emergence	Germination parameter

2.8: Metolachlor Qualities That Influence Cole Crops Parameters.

Metolachlor herbicide is a protein synthesis inhibitor (Buser, 2001). Crops rich in high protein can be severely destroyed by Metolachlor herbicide applications (Miller & Libbey, 2005). There are additives involved in product formulations to assist in protecting sensitive crops like sorghum from injury (Miller & Libbey, 2005). Movement and transportation are usually in an upward direction and inhibit plant growth (Miller, 2005). Selectivity of Metolachlor is based on the tolerant level of the plants to imbibe the herbicide faster compared to sensitive plants (Weed Science Society of America, 1994). Hence, weeds are eliminated before emergence, shortly after emergence, or at emergence (Miller, 2005). Shootuptake is more visible than root uptake (Miller, 2005). Metolachlor is usually used on maize, soybean, peanuts, sorghum, potatoes, cotton, sunflower, and woody ornamentals (Extoxnet, 2000b). No articles on direct-seeded broccoli hybrid cultivars' tolerance to Metolachlor herbicide in South Africa have been published.

Metolachlor Physical And Chemical Properties.

Metolachlor herbicide (Fig 2.8) in a pure state is known to be a colorless and odorless liquid at room temperature. Its colors vary from opaque white to tan in formulations (Sikkema et al., 2007). Metolachlor is a member of the chloroacetanilide chemical family (Sikkema et al., 2007).

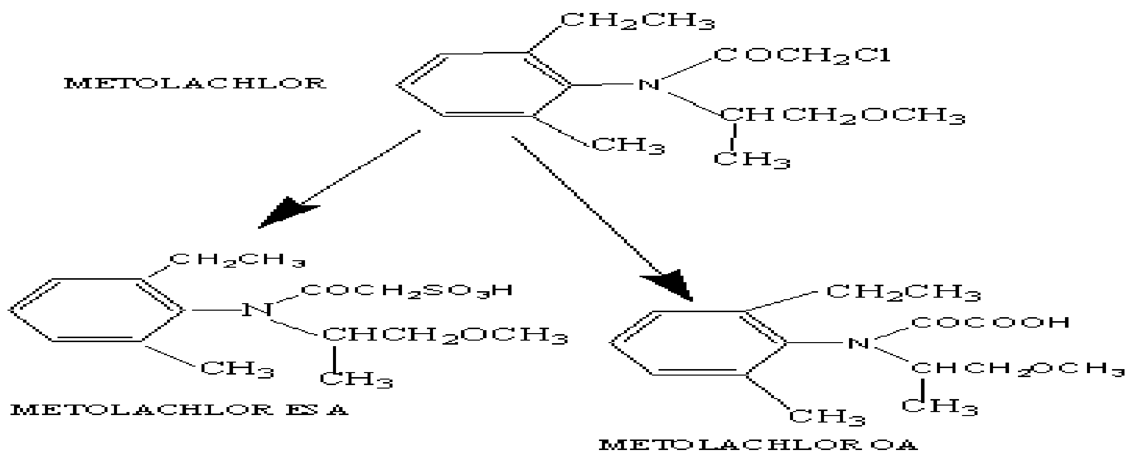

Figure 2.8: Metolachlor Chemical Structure (Rivard, 2003)

The chemical name for Metolachlor is *2 chloro-N-(2-ethyl-6- methyl phenyl)-N-(2-methoxy-1-methyl ethyl) Acetamide*. Metolachlor is a chloroacetanilide herbicide that is manufactured and made accessible as an emulsifiable concentrate (Sikkema et al., 2007).

Table 2.2: Metolachlor Chemical-Physical Qualities (Rivard, 2003)

Common Name	: Metolachlor
IUPAC Name	:*2-chloro-N-(2-ethyl-6-methylphenyl)-N-(1-methoxypropan-2-yl) acetamide*
C.A. Name	:[*2-chloro-N-(2-ethyl-6-methylphenyl)-N-(2-methoxy-1-methylethyl) acetamide*]
Chemical Family	: Chloroacetanilide
Empirical formula	: $C_{15}H_{22}ClNO_2$
Molecular weight	: 283.46 g/mol
C.A.S. No.	: 87392-12-9
Water solubility	: 530 mg/L (20°C)
Vapour pressure	: 1.3×10^{-5} mmHg (20°C)
Melting Point	: -62.1^{o}C
Density	: 1.12 g/cu cm at 20°C
Explosion Hazard	: Nonexplosive
Physical state	: Emulsifiable concentrate
Odour	: Odourless clear liquid
Colour	: Colorless liquid
Flash Point	: Greater than 230°F

2.8.1:Mode of Action, Characteristics And Universal Information Of Metolachlor.

Metolachlor is a pre-emergent herbicide that is used the control certain broadleaf weed species and annual grassy weeds yellow nutsedge (*Cyperusesculentus*), barnyard grass (*Echinochloacrusgalli*), crabgrass (*Digitaria* spp.), fall panicum (*Panicumdichotomiflorum*), and foxtails (*Setaria* spp.). Metolachlor essentially was manufactured in 1972 by Ciba-Geigy Limited, Basel Switzerland (Weed Science Society of America, 1994) but was officially registered in 1977. Its means of absorption is through the roots and shoots of germinating plants, movement is usually known to be in an upward direction which inhibits plant growth (Miller, 2005). Reduction in both cell division and enlargement is the reason for the growth inhibition caused by Metolachlor herbicide (Norsworthy, 2006). Longitudinal growth is reduced faster when compared to lateral growth (Miller, 2005); this results in affected roots' compact appearance (Al-Khatib et al., 1995). Selecting Metolachlor herbicide is delicate since there is a high tendency of tolerant plants to consume the molecule more quickly when compared to receptive plants (Weed Science Society of America, 1994).

The level of herbicide transport in the spot of application is dependent on several factors such as application rate, herbicide persistence and mobility, rainfall, topography, and climate (Linetal, 1999). The degradation processes include microbial, photodecomposition, and chemical, thus resulting in a reduction of the herbicide adsorption in the soil. The movement of the herbicides to various parts of the environment by wind, runoff erosion, leaching, and volatilization. Runoff erosion and leaching movement can lead to groundwater and soil surface contamination (Sanyalet al., 1999). The fate and herbicide movement of metolachlor within the soil are quite affected by degradation and sorption processes (Akers et al., 2000). Metolachlor is acknowledged to be adsorbed fairly to the soil. The adsorption rates of the product increase sequentially with the clay content and soil organic matter and can slow its mobility in soil. Irrigation and rainfall can help in transporting metolachlor faster to groundwater. Shoot and root parameters are influenced by Metolachlor herbicide.

2.8.2: Effects Of Metolachlor On Cole Crops.

Metolachlor belongs to the chloroacetanilide family, which could be applied as early pre-transplant incorporated, pre-transplant, or post-transplant to eliminate and control annual grasses and broad-leaved weeds (Sikkema et al., 2007). Miller and Libbey (2005) discovered that Metolachlor application rate at about 0.5 lbai/ha has been registered in spinach seed crops in Washington for some past years.

A pre-emergence application of Metolachlor herbicide on cabbage, tomatoes, and cucumber was conducted, the results showed that metolachlor had an inconsistent tolerance on these crops (Gorski, 2008). It was discovered that the tomato and cucumber germination rate lowered with an increasing metolachlor dosage. Lettuce crop germination at 0.56 kg/ha and above was subdued. Burgos, (2006) performed an herbicide trial on spinach and southern greens, Prodiamine, Dimethenamid-P, and Metolachlor were cool on spinach when applied post-emergence rather than pre-emergence. Also, a comparable report was made by Batts (2006), that leafy cole crops were tolerant to Metolachlor. According to Sikkema et al., (2007) from a trial demonstrated on the pre-transplant incorporated application of metolachlor on cabbage at 0.8l/ha, 1.6l/ha, and 2.4l/ha application rates, there was no visual injury, marketable head number, marketable head weight and yield of cabbage at any of the Metolachlor application rates or application timings evaluated. Sikkema et al., (2007) suggested that Metolachlor at the doses evaluated has the potential for use in cabbage in Ontario. Metolachlor pre-emergence soil-applied at 0.5l/ha on broccoli was observed to be safe (Fennimore, 2006) it efficiently eliminated summer/spring weeds better than the Dacthal standard. Metalochlor applied trial on cabbage was tolerated before transplanting (Al-Khatib et al., 1995).

Subsequently, a demonstration to evaluate the viability of pre-emergence metolachlor on cabbage revealed there were significant variations among cultivars in seedling weight loss and injury ratings both on the field and the greenhouse (Harrison et al., 1998). The demonstrations revealed that Metolachlor applied at 1.5 kg/ha or lower can be securely utilized in weed control for direct-seeded kale and collard if vulnerable cultivars are not used. Robinson et al., (2007) stated that metolachlor applied at different timings (pre-transplant incorporated, pre-transplant and post-transplant), has no variation in cabbage tolerance. Also emphasized that Metolachlor accessibility as a pre-transplant incorporated and pre-transplant herbicide for cabbage production would provide farmers a better with a result eliminating difficult weeds and to help ease the burden of work in the next planting season. Considering the results obtained, Metolachlor applied pre-transplant incorporated, pre-transplant and post-transplant at 800, 1600, and 2400 g a.i /ha had an acceptable level of the cabbage. Peterson, (2008) reported the control of weeds in cole crops with Metolachlor could be applied before or after transplanting.

2.9: Halosulfuron Qualities That Influence Cole Crops Parameters.

Halosulfuron belongs to the sulfonylurea herbicide family (Group 2) (Senseman, 2007). It is a new highly active sulfonylurea herbicide that has been widely used for weeding control in a variety of vegetables and other cucurbits crops (Umeada, 2011). It is used to control annual grasses and other broad-leaved weeds such as pigweeds. The product is available in white powder, granules form which is used by mixing with water and making it in suspension formulations before it is applied to the desired crop. Halosulfuroin is moderately absorbed in soils; research conducted indicated that Halosulfuron adsorption to soil colloids was greatly correlated with soil organic carbon content and inversely related to soil pH (Dermiyati & Yamamoto ,1997a). Degradation of Halosulfuron increases with increasing temperature and a lower soil pH, which contains soil moisture content and soil type further affecting residual effect (Dermiyati & Yamamoto, 1997b). Halosulfuron can also be degraded by microbial degradation and through chemical hydrolysis (Grey et al., 2007). Halsoulfuron plays a role as an inhibitor of branched-chain amino acid production by inhibition of the enzyme acetolactate synthase (ALS) or acerohydroxy acid synthase (AHAS). No articles on direct-seeded broccoli hybrid cultivars' tolerance to Halosulfuron herbicide in South Africa have been published.

Halosulfuron Physical And Chemical Properties

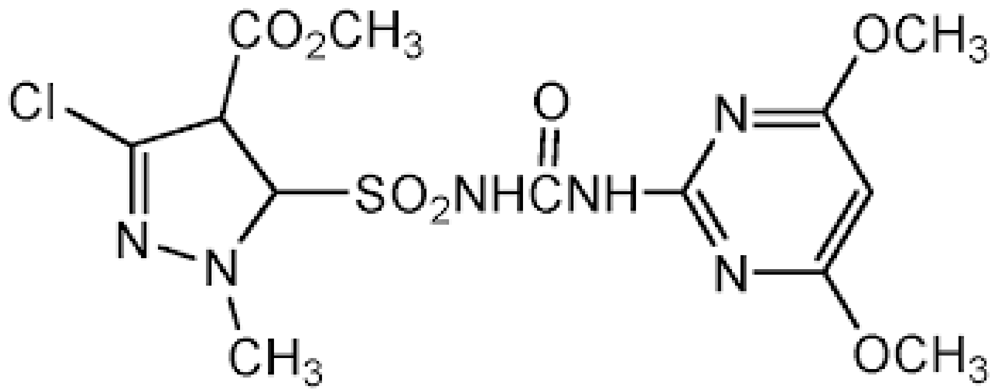

Figure 2.9: Halosulfuron Chemical Structure,
(http://m.chemicalbook.com/ChemicalProductProperty_EN_cb6690573.htm)

Halosulfuron-methyl(*methyl 3-chloro-5-[(4, 6-dimethoxypyrimidin-2-ylcarbamorylsulfamoyl)]-1-1-methylpyraxole-4-carboxylate*) belongs to the pyrazole; pyrimdinysulfonylurea; sulfonylurea family. Halosulfuron is more efficacious on annual broadleaf weeds when applied PPI or PRE than POST emergence (Brown &Masiunas,2002).

Table2.3: Halosulfuron Chemical-Physical qualities. (https://pubchem.ncbi.nlm.nih.gov/compound/Halosulfuron-methyl#section=Top)

Common Name	: Halosulfuron
IUPAC name	:*methyl 3-chloro-5-(4,6-dimethoxypyrimidin-2-ylcarbomorylsulfamoyl)-1-1-methylpyrazole-4-carboxylate*
C.A. name	:*methyl 3-chloro-5-[(4, 6-dimethoxy-2-pyrimidinyl)amino] carbamoyl]amino]sulfonyl]-l-methyl-1H-pyrasole-4-carboxylate*
Chemical Family	: Sulfonylurea
Empirical formula	: $C_{13} H_{15} ClN_6 O_7S$
Molecular Weight	: 434.81 g/mol
C.A.S. No	: 21087-64-9
Physical State	: White powder
Melting Point	: 175.5 -177.2°C
Density	: 1.62 g ml^{-1}
Odour	: Weak characteristic odour
Vapour Pressure	: <1 X 10^{-5} Pa
Flash Point	: Technical and formulated products are dry and non-inflammable
Explosion Hazard	: Nonexplosive
Solubility in water	:15 mg/ l ($_p$H 5,25°C);1630 mg/ l($_p$H 7,20°C)

2.9.1: Mode Of Action, Characteristics And Universal Information Of Halosulfuron.

Halosulfuron is soluble in water (1630 mg/L at 20°C, PH 7) and is reported to be an inhibitor of acetolactate synthase (ALS), an enzyme involved in the biosynthesis of branched-chain amino acids (Brown, 1990) including valine, leucine, and isoleucine (Duggleby et al., 2008). Halosulfuron can be absorbed by both roots and foliage, inhibiting the growth of susceptible plants (Soltani et al., 2009). Halosulfuron herbicides have a wide range of crop selectivity, are low use rate herbicides, have high efficacy, and have low mammalian toxicity (Senseman, 2007). Globally, there are more than 50 active ingredients that are ALS inhibitors (Boutsalis, 2001). Halosulfuron applied pre-plant incorporated (PPI) provides control of many annual broadleaf weeds including redroot pigweed (*Amaranthus retroflexus L*.), velvetleaf (*Abutilon theophrasti Medic*), common cocklebur (*Xanthium pennsylvanicum L.*), jimsonweed (*Datura stramonium L*.), lady's thumb (*Polygonumpersicaria L*.), and wild mustard (*Sinapis arvensis L.).*It controls nutsedge species (*Cyperus*spp.) (Senseman,2007). Weed injury symptoms usually appear within 5 to 7 days, including chlorosis and necrosis of the growing point, cessation of plant growth, and reddening of the veins of the lower leaf surface (Senseman, 2007). Unlike some of the early sulfonylurea herbicides such as chlorosulfuron and metsulfuron which have long persistence in the soil, Halosulfuron has a half-life in the soil of 1 to 27 days (Amrhein& Gerber 1985; Baber &Marmor 2002; Senseman, 2007). Likewise, it was indicated that the half-life of Halosulfuron ranges from 6 to 98 days, this quite depends on the soil moisture and temperature management (Dermiyati& Yamamoto 1997b; Grey et al., 2007a) and it exhibits hysteresis (Carpenter et al., 1999). In contrast to some other sulfonylurea herbicides such as foramsulfuron and nicosulfuron which provide limited residual weed control, Halosulfuron provides full season residual broadleaf weed control. The level of injury recorded from the residual effect of Halosulfuron to the rotational crops has occurred as a result of the varying soil behavior (Grey et al., 2007b) the herbicide will hydrolyze more rapidly when soil pH is less than 4.5. The lower rate of Halosulfuron (35 gai/ha) is recommended on lighter textured with low organic matter soils (Senseman, 2007). Halosulfuron is a low-dose herbicide that provides residual control of broadleaf weeds.

2.9.2: Effects Of Halosulfuron On Cole Crops.

Umeada, (2011) reported that Halosulfuron herbicide had no effect on crop stand when lettuce, broccoli, alfalfa, spinach, onion, and barley were planted alongside cantaloupes. The plant numbers of each crop that was counted were equal to the untreated trial. The researcher also reported that a slight injury up to 16% was obtained from the cantaloupes at 29 days after planting of the PREE treatments and 9 DAP of the POST treatments slightly more unacceptable injury level-up to 28% was observed for PREE plus POST treatments on the cantaloupes. Visual injury observed was much lesser than 10% at 8 weeks after planting of the PREE treatments and 5 WAP of the POST treatments applied sequentially or singly.

Halosulfuron can be applied pre-plant incorporated (PPI), preemergence (PRE), or postemergence (POST) in white beans (Soltani et al., 2009). Halosulfuron shows a greater crop safety when applied PPI or PRE when compared with the POST in white bean production (Soltani et al., 2009). Halosufuron is more effective on most annual broadleaf weeds when applied PPI and PRE than POST. According to Brown and Masiunas (2002), Halosulfuron applied PRE provided better control of redroot pigweed, velvetleaf, and lamb's-quarters 3 weeks after it was applied (WAA), respectively. Whilst Halosulfuron when applied POST, controlled a very small quantity of lamb's quarters in a trial demonstrated by (Soltani et al., 2013a). Soltani et al., (2009) evaluated the crop safety of Halosulfuron applied at 35 and 70 g ai /ha PPI, PRE, and POST to black, cranberry, kidney, otebo, pink, pinto, small red Mexican (SRM), and white beans in Harrow, Ridgetown, and Exeter, Ontario. It was reported that Halosulfuron applied PPI, PRE, and POST caused 1%, 2%, and 5% crop injury, respectively. The injury symptoms caused by Halosulfuron included chlorosis, necrosis, stunting, and death of the growing point (Soltani et al., 2009). Earlier demonstrations revealed that the tolerance of these

Cole crops to herbicides differs (Harrison, 1998). Umeada, (2011) in his research also reported that at the time of harvest, the alfalfa crop had a slightly reduced fresh weight of whole plants where Halosulfuron herbicide was applied PREE only. Unlike the other instance where Alfalfa plants were planted sequential PREE plus POST treatments were applied showed no significant reduction. The spinach plants that were planted where POST applications were made on cantaloupes were likely to show a slight reduction in fresh weight when compared to the untreated trial and where PREE treatments were applied. Broccoli and lettuce fresh weights did not exhibit differences between treatments and the untreated trial. Halosulfuron applied PPI or PRE provides annual broadleaf weed and sedge control. Grichar et al., (2009) reported 92% purple nutsedge control with Halosulfuron applied PRE at 66 g ai/ha. In contrast, (Webster,2006) found that Halosulfuron applied PRE was less effective for the control of yellow nutsedge than when applied POST. Halosulfuron applied PRE at 27 gai/ha provided control of morning glory species in cucumber production (Trader et al., 2007).

2.10: Clomazone Qualities That Influence Cole Crops Parameters.

Clomazone (2-(2-chlorophenyl) methyl-4, 4-dimethyl-3-isoxazolidinone; was first approved for use in 1986 (US EPA 2007). It is manufactured by the FMC Corporation under the trade names that include Command® and Cerano® 5 MEG (Tenbrook et al., 2006). Clomazone herbicide is the only isoxazolane herbicide recognized and approved for use within the United States (US EPA 2007). Mainly utilized in the control of grassy weeds and annual broad-leaf such as barnyard grass (*Echinochloa crus-galli*), crabgrass (*Digitaria* spp.), foxtails (*Setaria* spp.), and including others that plague tobacco, soybean, rice, and other row crops (Scott et al., 1995; Lee et al., 2004; Schocken, 1997). This herbicide is prepared as an emulsifiable concentrate and micro-encapsulated flowable granule (5% Clomazone) and it is applied either pre-or post-emergence (CDPR 2003; US EPA 2007). Clomazone is a very selective herbicide for weed control in soybeans and pumpkins and is currently under investigation for use in other horticultural crops (Scott & Weston, 1992; Scott & Weston, 1990).

Clomazone is highly water-soluble and moderately persistent in soils with half-lives ranging from 5 to 60 days. Due to its water solubility nature, the potential impact of clomazone on surface water, groundwater, and aquatic organisms is of great concern. At room temperature, it is extremely soluble in water and has a low-to-moderate affinity for soil. In weight, clomazone herbicide is denser than water and is vulnerable to microbial degradation. Moreover, its rate of sorption to various soil types (with varying temperature and moisture) has been scrutinized. Mervosh et al., (1995b) reported that a concentration of ca. 9 mg/kg of 14C- clomazonesorbed to a silty clay loam soil; that such sorption was independent of temperature and soil moisture content had a minor sorptive effect. Even though its overall soil sorption is low; the agent has greater attractions for binding to humic acid than to whole soil (Gunasekara et al., 2009). Quayle et al., (2006) applied clomazone to simulated flooded rice plots and measured resulting soil concentrations. Clomazone when applied in buffered solutions (pH 4.65, 7.0 and 9.25, 25°C, 41d) it was found to be hydrolytically stable over the entire test period (Dziedzic, 1982). The rate of the herbicide breakdown was <10% of the initial concentration at each pH, but the natures of the resulting products were not evaluated. CDPR (2003) reported similar observations, discovering that Clomazone was stable under various pH conditions, as measured after 34-40 days. Liu et al., (1996) experimented *Aspergillus niger* and *Cunninghamella echinulata,* a common soil fungus, and bacterium, respectively, to Clomazone; 95% of the agent was metabolized by *A. niger*. Mervosh et al., (1995a) investigated both the mineralization and microbial degradation of 14C Clomazone in Flanagan silt clay loam soil and found mineralization to be dependent on microbial activity; mineralization was more active at lower temperatures. As reported by Mills et al., (1989), microbial degradation of clomazone is favored under neutral soil pH conditions, while microbial populations tend to be more abundant under no-till conditions. In a series of studies, clomazone has been observed to degrade more rapidly under flooded conditions, suggesting that anaerobic bacteria play an important role in degrading it. Tenbrook et al., (2006) reported that microbial degradation of clomazone could be due to photolytic enhancement; although, to date, this fact has not been experimentally established or proven. Lack of photolytic assistance was further confirmed by Tomco & Tjeerdema, (2012). They did discover soil microbial degradation to be more relevant than photolysis, and thus, it appeared to be the major degradative pathway for clomazone (Tomco & Tjeerdema, 2012).

No article on direct-seeded broccoli hybrid cultivars' tolerance to clomazone herbicide in South Africa has been published.

Clomazone Chemical And Physical Properties.

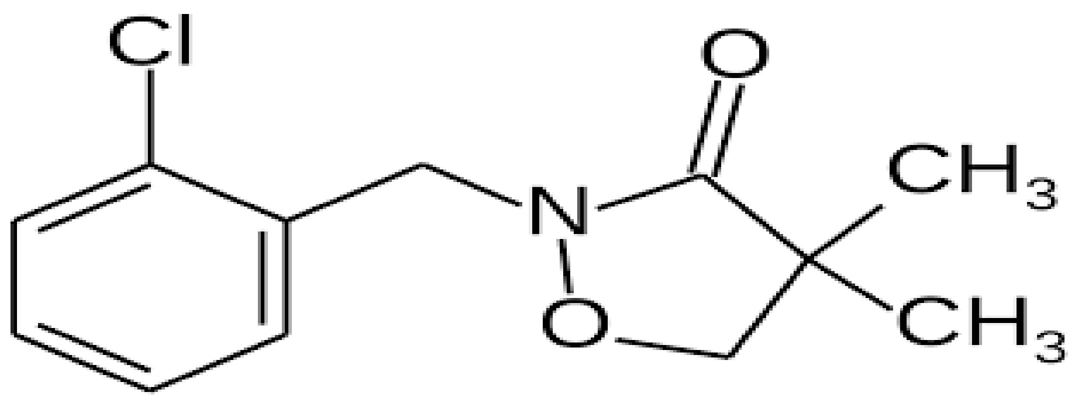

Figure 2.10: Chemical structure of Clomazone. **(**http://m.chemicalbook.com/ChemicalProductProperty_EN cb6690573.htm)

Clomazone herbicide (*2-(2-chlorophenyl) methyl-4, 4-dimethyl-3-isoxazolidinone*; was first approved for use in 1986 (US EPA, 2007). It is produced by the FMC Corporation under the trade names that include Command® and Cerano® 5 MEG (Tenbrook et al. 2006).

Table2.4: Clomazone Chemical-Physical Qualities (http://m.chemicalbook.com/ChemicalProductProperty_EN_cb6690573.htm)

Common Name	: Clomazone
IUPAC Name	:*2-[(2-chlorophenyl) methyl]-4,4-dimethyl-1,2-oxazolidin-3-one*
C.A. name	:*2-(2-chlorophenyl) methyl-4,4-dimethyl-3-isoxazolidinone*
Chemical Family	: isoxazolane
Empirical formula	$C_{12}H_{14}ClNO_2$
Molecular Weight	239.699 g /mol
C.A.S. No	81777-89-1
Physical State	: viscous liquid
Melting Point	: 175.5 -177.2°C
Density	: 1.192 at 25°C
Odour	: Solvent like
Vapour Pressure	: $1.4X10^{-4}$ mm Hg at 25°C
Flash Point	:emulsifiable concentrates products are dry and non-flammable
Explosion Hazard	: Nonexplosive
Solubility in water	: 1,100 ppm at 25°C

2.10.1: Mode Of Action, Characteristics And Universal Information Of Clomazone.

Clomazone herbicide is intended to control broad-leaf grasses; though, it has been known to cause toxicity in some other plants, in which it systemically, dynamically penetrates through the roots and shoots, and translocates through the xylem (US EPA, 2007). It is understood that the metabolite 5-ketoclomazone may be responsible for such toxicity (US

EPA 2007). Earlier findings have shown that this herbicide disrupts the formation of photosynthetic pigments, reducing both chlorophyll, carotenoids, and bleaching foliar structures. Harrison & Farnham, (2012) carried out greenhouse research on broccoli and cabbage to clomazone tolerance, it was reported that the comparison that existed between the visual injury and early growth reduction in broccoli and cabbage, and differences in the clomazone tolerance observed in their trial correspond to those observed in their field experiment and those demonstrated by (Hopen et al., 1993). Clomazone comes as a Clear colorless to light brown viscous liquidThe product comes as emulsifiable concentrates that are non-flammable so it is quite stable at ambient temperatures for at least 2 years; stable at 50°C for at least 3 months and can be stored. Clomazone herbicide is an isoxazole herbicide that contains a chloroaromatic ring. In a pure state, clomazone is a crystalline solid (CDPR, 2003). But at room temperature, it is extremely soluble in water and has a low-to-moderate affinity for soil. This herbicide is denser than water and is susceptible to microbial degradation. Clomazone is not expected to bind to soils strongly given its relatively low Kd and its hydrophilic nature. The explosive nature of different formulations of clomazone from Flanagan silt loam was studied under both moist soil and simulated rainfall conditions. Mervosh et al., (1995c) did report that each of the granular formulations reduced volatilization; small granules (20 to 30 meshes) produced greater volatilization than did those of 14 to 20 mesh. Surface water photolytic degradation adds to the dissipation of many pesticides and other xenobiotics. Zanella et al., (2008) examined the photodegradation rate of clomazone in both distilled and agricultural field water; results obtained showed that clomazone was anaerobically degraded to produce metabolites within 3 days of its application. But the case was different under aerobic conditions, clomazone residues became soil-sorbed residues (Tomco et al., 2010). The aerobic and anaerobic half-lives of clomazone were reported to be 7.9 days and 47.3 days, respectively.

According to (Harrison & Farnham, 2011) Clomazone does influence the critical plant growth parameter which includes visual leaf injury, the shoot weights, plant height, and stunt count of cabbage-based on the different levels of concentration or application rates.

2.10.2: Effects Of Clomazone On Cole Crops.

Clomazone herbicide is registered for weed management in both direct-seeded and transplanted cabbage production in countries like the United States of America whilst it is a banned herbicide in California (FMC Corp., 2005). Though it is not registered for broccoli, brussel sprouts (*B.oleracea* Gemmifera group), collards (*B. oleracea* Acephala group), cauliflower (*B. oleracea* Botrytis group), kale (*B. oleracea* Acephala group), and others within the same species in the United States of America. Clomazone is very effective in weed control for cabbage and quite several other vegetable crops because it provides residual control of several important annual kinds of grasses and broadleaf weeds. The recommended application rates for Clomazone for all crops range from 0.15 to 1.5 Ib/acre and are based on crop level of tolerance and soil type. Clomazone when applied at higher rates recommended for highly tolerant crops, controls more weed species and provides longer-lasting control than the low rates suggested for less tolerant crops. The recommended application rates for transplanted cabbage are 0.25 and 0.5 lb/acre for coarse and fine soils; Clomazone also can be used on direct-seeded cabbage at up to 0.5 lb/acre.

The mode of action, particularly on the methylerythritol-4 phosphate (MEP) pathway, resulting from clomazone, 5-hydroxyclomazone, and 5 ketoclomazone, has been examined. Ferhatoglu & Barrett (2006) also reported that clomazone and 5-hydroxyclomazone did not inhibit the MEP pathway in spinach, even though they are known to cause plant bleaching; however, 5-ketoclomazone did inhibit this pathway. Ferhatoglu& Barrett (2006) concluded that subsequent toxicity and plant bleaching results from the ultimate toxicant 5-ketoclomazone. Hopen et al., (1993) assessed the response of 36 genetically diverse cabbage cultivars to clomazone applied before transplanting.

Their findings showed that most of the cultivars were tolerant of Clomazone, chlorosis was minor and short-lived, and yields were not reduced. Also, the natural variation in Clomazone tolerance among cultivars or genotypes within crop species has been reported for bean (*Phaseolus vulgaris)* (Sikkema et al., 2006), maize (*Zea mays)* (Keifer., 1989), cucumber (*Cucumis sativus)* (Al-Khatib et al., 1995; Staub et al., 1991), pumpkin (*Cucurbita maxima*, *C. moschata*, *C. pepo)* (Harrison & Keinath, 2003), rice (*Oryza sativa)* (Mudge et al., 2005; Scherder et al., 2004; Zhang et al., 2004), sweetpotato (*Ipomoea batatas)* (Harrison & Jackson, 2011), and watermelon (*Citrullus lanatus)* (Harrison et al., 2011). The study was aimed at assessing the Clomazone tolerance of broccoli cultivars in comparison with cabbage cultivars using greenhouse and field experiments to assess the potential for safely using clomazone for weed management in broccoli. Harrison et al., (2011) performed their research to evaluate the effects of clomazone on the early growth of broccoli in the greenhouse, the clomazone was applied PRE incorporated into the potting medium, Clomazone concentrations were 0, 1.0, 2.0, and 4.0 ppm/ha in the potting medium, they reported that from the analysis of variance obtained, visual injury rating and shoot weight data did show that the interactions between experiments and treatments were significant. According to their findings, shoot weights of the cabbage at 1.0 ppm Clomazone were less than 50% of the control shoot weights and broccoli shoot weight was reduced over 50% by 1.0 ppm application rate. Harrison et al., (2015) in a greenhouse experiment with Clomazone on diverse genetical hybrid cultivars, it was reported that tolerant cultivars were slightly injured and growth was not affected by clomazone incorporated into the potting medium at 3.0mg/kg; however susceptible cultivars were severely injured and their shoot weights were reduced by 1.5mg/kg. In general, Harrison et al., (2015) reported that the recommended clomazone rate of 0.28kg/ha for cabbage on sandy soils is relatively safe for the genetically diverse broccoli used in the experiment.

2.11: OxadiazonQualities That Influence Cole Crops Parameters.

Oxadiazon is used in a few crops primarily soybeans and rice due to its mode of action, it is an inhibitor of Protox (Anderson et al., 1994). It is a protoporphyrin oxidase (Protex) –inhibiting herbicides which is an important component of weed management in conventional soybeans, corn, and sunflower throughout the midwestern United States to control and eradicate annual broadleaf weeds and suppress annual grasses. Most common summer annual broadleaf weed species found in usual soybean cropping mechanisms such as *Amaranthus* spp., *Ipomoea* spp., velvetleaf (*Abutilon theophrasti* Medicus), and jimson weed (*Datura stramonium L.*), are controlled by proton-inhibiting herbicides (Bailey et al., 2002; Johnson et al., 1978; Krausz et al., 1998; Wilson et al., 2002). Post-emergence herbicide trials carried out by Grieg &Gwin, (1969) in Kansas revealed that oxadiazon was selective in seeded onions and proved more effective in reducing the weed population as compared to its pre-emergence application. Noll, (1971) reported that the most promising herbicide in ol1lons grown from transplants on a mineral soil was oxadiazon at 4 lb per acre and applied 1 or 30 days after transplanting. Lee et al, (1973) obtained excellent weed control results in sweet Spanish onions with oxadiazon at 2lb per acre applied at planting to transplant rows. Oxadiazon at 0.75kg/ha applied as postemergence treatment gave good control indirectly sown onion cv. valenciana'sSintetica on a clay loam soil with 5 to 7 percent organic matter content and manual weeding was required before the crop was ready for harvest (Armelina, 1974). Sanok&Weber, (1975) achieved excellent weed control with oxadiazon at 1 to 4 lb/acre before weed emergence in transplanted onions on sandy loam soil without any significant effect on the yield. The higher rates gave longer control of the weeds present. Bisen et al., (1981) reported that oxadiazon at 0.5kg/ha pre-emergence showed effective control of *Echinochloacolonum*, *Ageratum conyzoides*, *Phylanthusniruri*, *Corchorus*spp, and *Alysicarpusrugosus*. Orkwar et al., (1981) stated that application of oxadiazon at 1 and 2 kg/ha before the transplanting of onion gave excellent weed control. Patel et al., (2011) advocated that both the level of oxadiazon (0.5 and 0.6 kg/ha) and the lower level along with one weeding at 40 OAT is quite effective in controlling weed growth

Roberts & Bond, (1984) tested several herbicides as a postemergence treatment for onions, and 250 g oxadiazon/ha at the one leaf stage was found promising. Sharma et al., (1984) noted that pre-emergence application of 0.75 and 1.0 kg oxadiazon per ha gave more effective weed control in garlic than mulching.

Khurana et al., (1985) advocated that the application of 0.75 kg oxadiazon and 1.0 kg pendimethalin/ha to an onion, gave excellent control of broad-leaved weeds.

No article on direct-seeded broccoli hybrid cultivars' tolerance to oxadiazon herbicide in South Africa has been published.

Oxadiazon Chemical And Physical Properties.

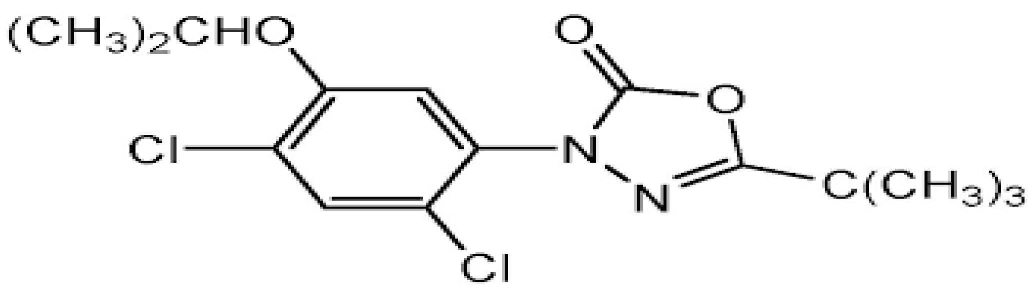

Figure 2.11: Chemical structure of Oxadiazon (BCG Media Release, 2008)

Table 2.5: Oxadiazon Chemical-Physical Qualities: **(**https://pubchem.ncbi.nlm.nih.gov/compound/oxadiazon#section=Top**)**

Common Name	: Oxadiazon
IUPAC name	: *5-tert-butyl-3-(2,4-dichloro-5-propan-2-yloxyphenyl)-1,3,4-oxadiazol-2-one*
C.A. name	: *1,3,4-oxadiazol-2(3H)-one, 3[2,4-dichloro-5-(1-methylethoxy)phenyl]-5-(1,1-dimethylethyl)-*
Chemical Family	: oxadiazole
Empirical formula	$C_{15} H_{18} Cl_2N_2O_3$
Molecular Weight	345.22g /mol
C.A.S. No.	19666-30-9
Physical State	: crystalline solid
Melting Point	: 90°C
Density	: 1.26 mg/l
Odour	: odourless
Vapour Pressure	: 1.15X10-7 mm Hg at 22°C
Flash Point	: Not applicable
Explosion Hazard	: Nonexplosive
Solubility in water	: 0.7 mg/l at 24°C

2.11.1: Mode Of Action, Characteristics And Universal Information Of Oxadiazon.

Oxadiazon herbicides are quite selective. A pre-emergence oxadiazole herbicide is used in a series of weed control such as annual grasses, sedges, brush vines, bramble, and broadleaf weed in vegetables and grain crops. Oxadiazon inhibits protoporphyrinogen oxidase PPO leading to irreversible cell membrane damage. Oxadiazon is classified as a Contact herbicide used for postemergence activity on young seedlings, though when used as a preemergence treatment it affects the shoot of sensitive weeds as they grow through the treated crops (Murphy, 1999). Oxadiazon is one of the most patented groups of inhibitors of Protox (Anderson et al., 1994). Oxadiazon is applied as foliar sprays which cause very rapid cellular collapse and desiccation. Oxadiazon is known to be a cell membrane disrupter herbicide, the last enzyme in the porphyrin pathway known as Protex is common to both heme and chlorophyll synthesis pathways. These compounds cause massive levels of the enzyme product (not the substrate) protoporphyrin IX (Proto IX) to accumulate through a complex mechanism involving both an herbicide-susceptible chloroplast Protox and an herbicide-resistant extra plastidicProtox IX-oxidizing enzyme (Jacobs et al., 1991; Jacobs & Jacobs, 1993; Lee et al., 1993; Nandihalli& Duke, 1993; Duke et al., 1994). Protox IX is a photosensitizing agent, generating highly reactive singlet oxygen in the presence of sunlight. Thus, Proto IX, a metabolic intermediate is the acutely toxic agent causing phytotoxicity. Although there is a wide range in the natural resistance of crops and weeds to these compounds (Sherman et al., 1991; Matsumoto et al., 1994), however, there is no evidence that any weeds have become resistant to these herbicides as the result of selection pressure. There have been several mechanisms of resistance, including the reduced sensitivity of Protox, metabolic rapid degradation of the herbicide, and resistance to singlet oxygen. There have been series of efforts made to produce a plant with an herbicide-resistant chloroplast Protox by either selection with Protox inhibitors (Che et al., 1993) or introduction of a resistant Protox from another organism (Sato et al., 1994).

Wehtje et al., (1993) found that Oxadiazon is sufficiently sorbed in the soil to prevent leaching based on displacement. Das et al., (2003) reported that the residual effect of the Oxadiazon is around 60 days after application.

Oxadiazon does influence the shoot and root growth parameters in Cole crops, such as; emergence and germination percentage, plant height, stunt count, necrosis, root length, and leaf injury (Sharma , 2007).

2.11.2: Effects Of Oxadiazon On Cole Crops.

Anonymous stated that a crucial problem with these herbicides that are Potex inhibitors such as oxadiazon herbicides is that, it appears to be selective to a few crops primarily soybeans and rice. Jablonska et al., (1975) reported that the best weed control in irrigated and un-irrigated cauliflower was obtained with BAS 2900H (Butrsan) at 8l/ha. The treatment had no adverse effect on cauliflower growth. Bhutani et al., (1978) found that Tenoran (chloroxuron) at 1 or 2kgai/ha was the most effective in controlling most weeds in cauliflower production. Deuber&Fornesier (1980) revealed that pendimethalin at 1.5 kg/ha and oxadiazon at 1.0 kg/ha had excellent selective control of both kinds of grass and broad-leaved weeds up to 115 days after treatment. It was also reported by Bhayan et al., (1985) that effective control of weeds with pendimethalin at 1.0 and 1.5 kg/ha and Oxadiazon at 1.0 and 1.5 kg/ha in cauliflower thus increased the availability of light, nutrients, and moisture of the crop.

Lee et al, (1993) found that flurachloralin was very effective against broad-leaved weeds in cauliflower and cabbage. She further reported that fluchloralin at 0.75 to 1.0 kg/ha was very effective against broad-leaved weeds in cabbage and cauliflower for 90 days.

Nandal et al., (1994) equally revealed that oxadiazon when applied at 1.0- 2.0 kg/ha and pendimethalin at 1.0 - 2.0 kg/ha reduced the weed densities up to 90 DAT and at harvest when compared with untreated control in onion crop. Hopen, (1995) suggested that due to increased environmental concerns, a combination of different types of weed control components i.e. herbicides; biological agents, and cultivation practices should be used.

2.12: Evaluations Of Gross Margin For Agricultural Inputs In Crop Production.

The gross margin could be defined as the total income obtained from an enterprise excluding the variable costs incurred in the enterprises. According to Ahmad, (2005) gross margin analysis involves the subtraction of the cost of goods or services sold from total sales made. Leslie, (2013) stated that the gross margin for a crop is defined as the received sales revenue from the marketed crop less the direct costs incurred in its production. Also, gross margin helps to establish the amount businesses make from the sale of goods and services before deduction of expenses which are also called overheads. Simply stated as: Gross margins = Revenue - Direct costs (variable costs) (Leslie, 2013). In agricultural farming businesses, the gross margin of a farming enterprise is the gross income obtained less the total variable costs incurred. In atypical agricultural farming enterprises, the total variable costs refer mainly to the total operating costs which include most of the inputs like chemicals, fertilizers, seed, transport, land preparation, and labor. The foremost advantage of gross margin analysis is to enable growers to decide on which crops to farm given various options (Karen, 2006). Gross margins assessment only has an inadequacy of not reflecting the true profit obtained from each crop because crops' total cost of sales reflects the expenditure related to raw materials, labor, and manufacturing overhead involved in its general production process. Loth, (1999) reported that expenditure is deducted from net sales/revenue accrued, resulting in a gross profit. The Gross Margin is frequently expressed as a percentage, also known as the Gross Margin Percentage, and is computed with the equation below using estimations;

Gross Margin Percentage =	Estimated Net Sales of *Broccoli* – Estimated Input Costs of *Broccoli* x 100 Estimated Net Sales of *Broccoli*

Gross Margin Budget For English Cabbage *(Brassica oleracea)*

Table 2.6: Gross Margins for Selected Fruit, Vegetable and Root Crops for the Sugar Cane Belt in Fiji, Leslie (2013), http://lrd.spc.int/

1. ASSUMPTIONS				
Spacing (m) 0.75 x 0.3	Planting density	(pl/ha) 26 000		
Yield Range 15,000 - 20,000	Average price ($/kg)	$1.50		
2. INCOME ($)	**Quantity**	**Unit**	**Unit Price**	**Total**
Sales	**17,500**	**kg**	**$1.50**	**$26,250**
Total Income				**$26,250**
3. DIRECT COSTS ($)	**Quantity**	**Unit**	**Unit Price**	**Total**
Land Preparation				
Ploughing	3	Ha	112.00	$336.00
Harrowing	2	Ha	84.00	$168.00
Furrowing/ridging	1	Ha	120.00	$120.00
Inter-row cultivation	1	Ha	80.00	$80.00
Planting Material				
Seed	15	20 pkt	0.50	$7.50
Fertilizers				
NPK(13:13:21)	3	40kg bag	93.74	$281.22
Urea	2	40kg bag	90.15	$180.30
Poultry manure	5	t	75.00	$375.00
Herbicide				
Agazone	1	10L	101.57	$101.57
Fungicide				
Sundomil	4	0.5kg	18.64	$74.56
Insecticide				
Steward	2	L	348.83	$697.26
Transportation	20,000	kg	0.10	$2000.00
Total variable Costs				**$4,421.41**
4. LABOUR INPUTS (person days)	**Unit**	**Quantity**	**Price $/Unit**	**Total $**
Description				
Planting	days	20	20.00	$400.00
Fertiliser Application	"	10	20.00	$200.00
Weeding	"	20	20.00	$400.00
Spraying	"	10	20.00	$200.00
Harvesting	"	20	20.00	$400.00
Total Labour Cost@$20/day		**90**		**$1600.00**
Total Cost				**$6,021.41**
Gross Margin per Ha				**$20,228.59**
Return per Labour Inputs				**$252.86**



Farmers and growers evaluate the financial implications related to weed management that has proven to be both efficient in controlling weeds and its cost-effectiveness financially (Habimana, 2014).

Herbicides applied as pre-emergence or pre-plant incorporated applied herbicides are most efficient in producing weed-free conditions for crops and produce a better financial strength when compared to hand weeding (Rao, 1999).

CHAPTER 3

3.0: MATERIALS AND METHODS.

3.1: Experimental Site.

A glasshouse experiment was conducted in 2017 using Clomazone, Metolachlor, Oxadiazon, and Halosulfuron trials effect on direct-seeded broccoli (*B.oleracea* var.cymosa) Hybrids in a fully automated Greenhouse at the College of Agriculture and Environmental Sciences, University of South Africa (UNISA) Florida Science Campus Horticultural Centre. The greenhouse temperature was adjusted to a 28°/18°C day/night temperature system. The thermoperiod, humidity, and precipitation set in the greenhouse were in a manner that simulates those obtainable in Magaliesburg magisterial area whose GPS coordinates are Latitude: S 25^{o} 52^{o} 775^{o} and Longitude E 27^{o} 22^{o}483^{o}.

3.2: Experimental Design.

Randomized Complete Block Design (Gomez & Gomez 1984) is the design chosen because the trial was a single factor experiment that was conducted in pots with 3 replications in a fully automated Greenhouse. Eight (8) different treatments (levels) per herbicide will be employed during one (01) growing season. Broccoli plants were planted in the greenhouse in June 2017, with Metolachlor herbicide, July 2017, with Clomazone, August 2017 with Halosulfuron, and September 2017, with Oxadiazon. Clomazone, Oxadiazon, Metolachlor, and Halosulfuron herbicides were applied at different levels to determine their effects on broccoli hybrids. Experimental homogeneity factors were maintained by regularly making uniformity in irrigation distribution as a way to reduce any experimental error. The control system of the greenhouse was automated according to the author's prescriptions in adjusting humidity, temperature, controlling light intensity, and monitoring the atmosphere. It had vents, fans, cooling, and heating systems which were automated in stages equivalent to the author's prescriptions and needs of broccoli. The soil was sieved and mixed thoroughly before filling them into the pots.

The following will constitute the Factor in this single factor experiment:

3.2.1: Experimental Variables.

Variables used in the research:

Factor: Herbicide (Clomazone, Oxadiazon, Metolachlor, and Halosulfuron) active ingredient with 8 levels plus control. The 7 application rates per active ingredients as depicted in the Table 3.3below which includes a Median that is selected from the suggested application rate for herbicides in weed management for other crops. Each herbicide application rate denoted the lowest rate as H1 and the highest denoted as H6.

Table 3.1: Hybrid denotation to be used in the trials

NO	HYBRIDS	DENOTATION
1	Primary Hybrid (Marathon F1 Hybrid)	B
2	Secondary hybrid (None)	N/A

3.2.2: Experimental And Treatments Layout

Table 3.2: Pre-emergent Herbicides used and the Application rates.

Active ingredients of Herbicides & Formulation	Application rates/ Ha							
(H1) Clomazone EC (480g/l)	0(con)	1ppm/ha	2ppm/ha	3ppm/ha	4ppm/ha(median)	5ppm/ha	6ppm/ha	7ppm/ha
(H2) Oxadiazon EC (250g/l)	0(con)	0.25l/ha	0.5l/ha	1.0l/ha	1.5l/ha(median)	1.75l/ha	2.0l/ha	2.5l/ha
(H3) Metolachlor EC(960g/l)	0(con)	0.4l/ha	0.8l/ha	1.2l/ha	1.6l/ha(median)	2.0l/ha	2.4l/ha	2..8/ha
(H4) Halosulfuron EC (750g/l)	0(con)	0.015l/ha	0.025l/ha	0.040/ha	0.055l/ha(median)	0.070l/ha	0.085l/ha	0.1l/ha

There will be a total of 7 treatments per herbicide and 1 control to be deployed in a Randomized Complete Block Design (RCBD) with three replications.

The treatments are displayed below in Table 3.3 in a schematic manner and not in the actual order in which the treatments will be assigned in the greenhouse. The treatments will be replicated 3 times. Note that the 8 treatments will each be randomly assigned to different 20cm diameter pots planting 2 seeds at 2cm apart in autoclaved washed sand. Note that the only variables in this experiment will be the different levels of herbicides. This means that all other factors will be employed as per standard agronomic recommendations for hybrid broccoli production.

Table 3.3: Treatments In Broccoli Trials For The Four (4) Herbicides:

HERBICIDE	Control	Rate 1	Rate 2	Rate 3	Median	Rate 4	Rate 5	Rate 6
Clomazone	B_0	BH_{11}	BH_{12}	BH_{13}	BH_{1m}	BH_{14}	BH_{15}	BH_{16}
Oxadiazon	B_0	BH_{21}	BH_{22}	BH_{22}	BH_{2m}	BH_{24}	BH_{15}	BH_{26}
Metolachlor	B_0	BH_{31}	BH_{32}	BH_{33}	BH_{3m}	BH_{34}	BH_{35}	BH_{36}
Halosulfuron	B_0	BH_{41}	BH_{42}	BH_{43}	BH_{4m}	BH_{44}	BH_{45}	BH_{46}

Key for denotations in Table 3.3:

Broccoli Hybrid: B
H means either of the herbicides used; Clomazone, Oxadiazon, Metolachlor or Halosulfuron.

B_0 is a denotation for broccoli hybrid having zero herbicide applied (Control)

BH_{11} is a denotation for broccoli hybrid treated with herbicide 01 at herbicide rate 01

BH_{48} is a denotation for broccoli hybrid treated with herbicide 04 at herbicide rate 08

3.2.3: Experimental Randomization Layout and Design.

The trial potswere arranged in a randomized complete block design (RCBD) each with three replicates in which each plant within a block were grouped on a greenhouse bench section.

Table 3.4: Block 1: A Sample of how the randomized Metolachlor block was done.

HERBICIDES TREATMENTS							
BH_{33}	BH_{36}	BH_{31}	BH_{34}	Control	BH_{32}	BH_{35}	BH_{3m}
Control	BH_{34}	BH_{32}	BH_{33}	BH_{3m}	BH_{36}	BH_{31}	BH_{35}
BH_{3m}	BH_{33}	BH_{35}	BH_{34}	BH_{36}	BH_{31}	BH_{32}	Control

Denotations: **Broccoli Hybrids**: B

H means Metolachlorherbicide applied at 7 levels

There was a total of 24 treatments plus control i.e(without Herbicide) trial which was 24 treatments including the control and replicated thrice to eliminate any chances of error as blocking effect was also introduced using a Randomized Complete Block Design. The 24 treatments were randomly assigned to pots in the greenhouse.

Table 3.5: Treatments in Broccoli Hybrids Trials

HERBICIDES TREATMENTS							
BC1	BC2	BC3	BC4	BC5	BC6	BC7	(BC0) Con
BM1	BM2	BM3	BM4	BM5	BM6	BM7	(BM0) Con
BH1	BH2	BH3	BH4	BH5	BH6	BH7	(BH0) Con
BO1	BO2	BO3	BO4	BO5	BO6	BO7	(BO0) Con

Denotations:

Broccoli: B

C means Clomazone

O means Oxadiazon

M means Metolachlor

H means Halosulfuron

Con means Control

3.3: Response of Shoot and Root Parameters Measurement and Data collection

3.3.1: Shoot and Root Parameters measurement

The shoot and root parameters measurement which were collected were the data used in the analysis of the sensitivity of the different herbicides applied. The parameters include; Emergence percentage, Plant height, Root Length, Visual injury, Stunt count, Necrosis percentage, Days to emergence, and Germination percentage.

(a) Emergence Percentage

The emergence percentage were measured by counting the numbers of emerged seedlings and comparing the treated seedlings with the untreated seedlings from date of planting, which was expressed in percentage of the number planted initially.

(b) Plant height

The plant heights were measured using a standard laboratory 30cm ruler.

(c) Root Length

The root length was measured using a standard laboratory 30cm ruler.

(d) Visual Leaf Injury

The visual leaf injury was obtained by physically counting the plants with injured leaves per treatment dosage and compared with the untreated and this was expressed in percentage.

(e) Stunt Count

The Stunt count wascollected by physically counting the plants that stunted per treatment dosage and compared with the untreated and this was expressed in percentage.

(f) Necrosis percentage

The Necrosis percentage was obtained by physically counting the plants that had necrotic conditions per treatment dosage and compared with the untreated and this was expressed in percentage.

(g) Days to emergence

The days to emergence were evaluated by noting the days the seedlings emerged from the planting date.

(h) Germination percentage

The germination percentage wasevaluated by counting the numbers of germinated seedlings and comparing the treated seedlings with the untreated seedlings from the date of planting, which was expressed in the percentage of the number planted initially.

3.3.2: Data Collection

The data were collected in a schedule pattern. The emergence and germination percentage and days to emergence were collected within 7 days while the other data were collected at 21 days and the experiments were terminated because pre-plant applied herbicides are only effective within 21-28 days after planting.

Table 3.6: Shoot and RootParameterswhichare Measurable

No	PARAMETER	EVALUATION TIME
1	Germination %	7 DAP
2	Emergence %	7 DAP
3	Days of Emergence	7 DAP
4	Plant height	21 DAP
5	Root length	21 DAP
6	Leaf injury %	21 DAP
7	Stunt count %	21 DAP
8	Necrosis	21 DAP

The above was the shoot and root parameters that were measured in the trial. These parameters were chosen by the author since the evaluations were assessed from germination to seedling stage up to three weeks (≤21 DAP). The soil-applied herbicides used by the author are the herbicides whose performances are apparent in seedlings of broccoli at the significant phase in efficient soil-applied herbicides. These parameters were assessable at the seedling stage of broccoli, in agreement with Wagner, (2006) that these shoots and root parameters are assessable at the seedling stage.

Plastic pots which were 20cm in diameter and 20cm high was used for the planting and each of the pots was placed with proper-sized plastic bags to prevent any contact between leaching from the sides of the pots and the herbicides. 1.5kg weight of Magaliesburg farming area clay loamy soil was filled into each pot, the soil which was filtered and mixed thoroughly.

Ten Broccoli seeds were sown at each point at a depth of 5cm. Each herbicide applied Pre-Incorporated, so the pots were left not weeded to grow with the seed to determine if the herbicides are good pre-emergence herbicides on weeds and crops.

Metolachlor was applied pre-incorporated before planting and a non-treated control pot was prepared as well. Metolachlor (960 EC) was applied at 7 rates plus the control, 0 (control), 0.4l, 0.8l, 1.2l, 1.6l, 2.0l, 2.4l, and 2.8l/ha application rate for the soil was utilized.

The herbicide was administered with the aid of a laboratory beaker and thoroughly hand-mixed for about 3minutes for each pot. Seeding was done immediately after incorporation.

Clomazone (48EC) was pre-incorporated soil-applied at 7 application rates plus control, 0 (control), 1ppm, 2ppm, 3ppm, 4ppm, 5ppm, 6ppm and 7ppm/ha application rate. The herbicide was applied to the soil with the aid of a laboratory beaker and wasthoroughly hand mixed for 3 minutes.

Planting of seeds was carried out as soon as the incorporation was done. Halosulfuron (75WG) was applied at 7 rates plus the control, 0 (control), 0.015l, 0.025l, 0.04l, 0.055l, 0.07l, 0.085l and 0.1l/ha application rate. The herbicide was administered with the aid of a laboratory beaker and was thoroughly hand-mixed for 3 minutes. Oxadiazon (25 EC) was soil-applied at 7 rates plus the control, 0 (control), 0.25l, 0.5l, 1l, 1.5l, 1.75l, 2l, and 2.5l/ha application rate. Application of the herbicide was done to the soil with the aid of a laboratory beaker and thoroughly hand-mixed for 3 minutes. Seeding was done immediately after incorporation as well. After each herbicide treatment, all the pots were irrigated with water at a level within 130 mm of the volume of water needed to wet the dry soil to field capacity. The termination of the plants was done 21 days after treatment and planting. The shoot and root growth parameters evaluations were taken at 7, 14, and finally 21 days after planting. Stunt count, Necrosis, Leaf Injury rating of 0% were referred to as no evident consequence of the herbicide, and death of plant is at 100%. Emergence and germination were rated on the percentage of the number planted. Five plants per plot were randomly selected and measured at 21 DAP. The Root length and Plant Height measurements were done in cm using a laboratory ruler. A value higher than 10% noticeable leaf injury is taken to be intolerable.

3.4: Technical Data Analysis and Interpretation.

- **ANOVA.**

  A One-way Analysis of Variance (ANOVA) for universal Linear Models was used to analyze variance or absence of variance of means. The evaluated Parameters response to herbicide sensitivity and tolerance in broccoli hybrids was achieved using SAS Version 9.4 at 95% confidence level (i.e. $P \leq 0.05$ significance test level). The value of Separation of Means, the author equally made use of Tukey's Multiple Comparison Test (also known as Honestly Significant Difference/HSD Test) to contrast and compare the mean separation value with those obtained from LSD.

- **Envisaged Sources of variations are:**
  - Treatment i.e. Rate of Herbicide (Halosulfuron, Metolachlor, Clomazone, and Oxadiazon) on broccoli hybrid replication (i.e. *Block*)
  - Random Error

- **Separation of Means.**

  In a bid to have a good knowledge of the data, it was ideal that Means of parameters of broccoli response be separated using Tukey's Multiple Comparison Test otherwise known also as (Honestly Significant Difference/HSD Test) (Gomez & Gomez. 1984) to compare the mean separation value obtained.
- **Verification of Sensitivity ofthe only Factor (Herbicide active ingredients with their 7 application rates plus a control) on the broccoli hybrid.**

  The researcher envisaged that there would be an effect of the only factor, the researcher decided to evaluate whether the sensitivity and tolerance of the factor differed as a result of different levels of treatment or as a result of the variations in the ingredients of the factor applied.
- **Determination of Coefficient of Variation.**

  The coefficient of Variation (CV) was evaluatedto judge whether the process of comparing treatments was done with accuracy. The CV articulates the experimental error as a percentage of mean and thereby as such it explains the reliability of the whole experiment. A satisfactory or acceptablemeans CV percentage of herbicides is below 15% and above 15% is not acceptable or satisfactory.

3.5: Evaluation of Gross MarginInvolved with the Use ofHerbicides application in Broccoli Production.

An estimation for the gross margins and gross profit margins per hectare in relation to the use of Halosulfuron, Clomazone, Oxadiazon, and Metolachlor herbicides were done and was estimated on the basis that the broccoli was grown to maturity and sold immediately after harvest without storage. Adeyemo et al., (2010) defined gross margin as the exclusion of Total Variable cost (TVC) from the Gross income (GI) obtained from the sales of the products, the gross profit margins were used as the central unit of investigation in evaluating the four herbicides usage feasibility. Gross margin = (GI – TVC) where Gross Margin = Gross margin, GI = Gross income, and TVC = Total variable costs were all calculated in rands value. Computing the gross margins and gross profit margins, broccoli is believed to be sold immediately after harvesting; thus, there was no need to cater for storage loss in the calculation. Maoba, (2016) described Gross margin as the value of net sales of produced goods, with the exclusion of the cost incurred in the production of the goods. Furthermore, Gross margin can be expressed in percentage using the principle below:

Gross Margin Percentage =	Estimated Net Sales of Broccoli – Estimated Input Costs of *Broccoli* x 100 Estimated Net Sales of *Broccoli*

(Maoba 2016)

CHAPTER 4

4.0: RESULTS

4.1: Effects Of Metolachlor Herbicides On Shoot And Root Plant Growth Parameters Of Broccoli Hybrid Seedlings.

4.1.1: Influence Of Metolachlor On Emergence Percentage Of Broccoli Hybrid Seedlings.

Table 4.1.1: Emergence percentage means ANOVA results as influenced by the seven application ratesof soil-applied metolachlor including the untreated.

Source	DF	Sum of Squares	% Emergence Mean	Mean Square	CV	F Value	Pr> F
Metolachlor	7	116.67	97.50	16.67	4.68	0.80	<.0.5989

4.1.1.1: ANOVA: The obtained results illustrate that, there were no significant differences in emergence percentage by the seven application rates of Metolachlor when compared to the untreated trial, also with an emergence percentage mean of 97.50% as shown above in Table 4.1.1

4.1.1.2:Metolachlor Mean Separations for Emergence percentage: Emergence percentage Mean separation results for the 7 application rates of soil-applied Metolachlor including the untreated. Figure 4.1.1 below depicts the results obtained fromMetolachlor Tukey's Studentized Range (HSD) Test for percentage emergence.

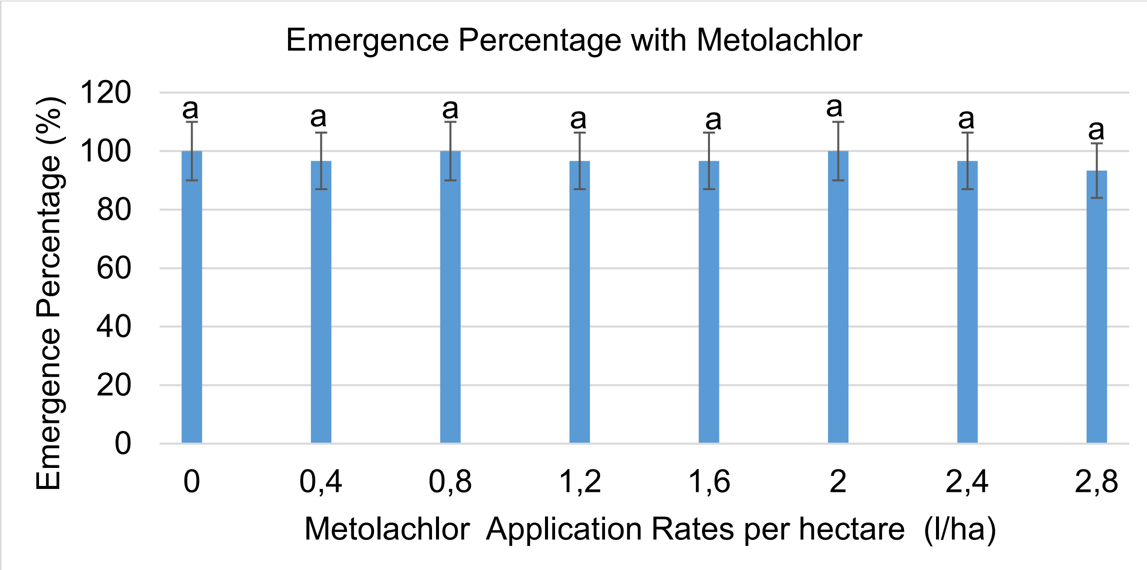

Figure 4.1.1: Graph of Emergence percentagefor Metolachlor application rates on Broccoli Hybrid Seedlings.

Figure 4.1.1 illustrates the emergence percentage of seedlings that emerged, averaged over the 7 treatments plus untreated. The emergence percentage was evaluated 7 days after planting. The results were allocated to one group alone. According to figure 4.1.1 above (Tukey's Studentized Range (HSD) Test), it is apparent that Metolachlor does not influence the emergence percentage of broccoli. There was no significant difference between the seven treatments and the untreated; they are all denoted with the symbol “a”. The treatments have no level of significance when compared with the control.

4.1.2: Effect Of Metolachlor On Plant Height Of Broccoli Hybrid Seedlings.

Table 4.1.2: ANOVA results for plant height means of broccoli hybrid seedlings as affected by 7 application rates of soil applied Metolachlor plus the untreated.

Source	DF	Sum of Squares	Plant Height Mean	Mean Square	CV	F Value	Pr> F

Metolachlor	7	21.97	4.12	3.14	11.24	14.65	<.0001

4.1.2.1: ANOVA: The obtained results illustrate that, there were significant differences in plant height by several application rates of Metolachlor when compared to the untreated trial,and a plant height mean of 4.12m as shown above in Table 4.1.2.

4.1.2.2:Metolachlor Mean Separations For Plant Height: Plant height mean separation results for the 7 application rates of soil-applied Metolachlor including the untreated. Figure 4.1.2 below depicts the results obtained fromMetolachlor Tukey's Studentized Range (HSD) Test for Plant height.

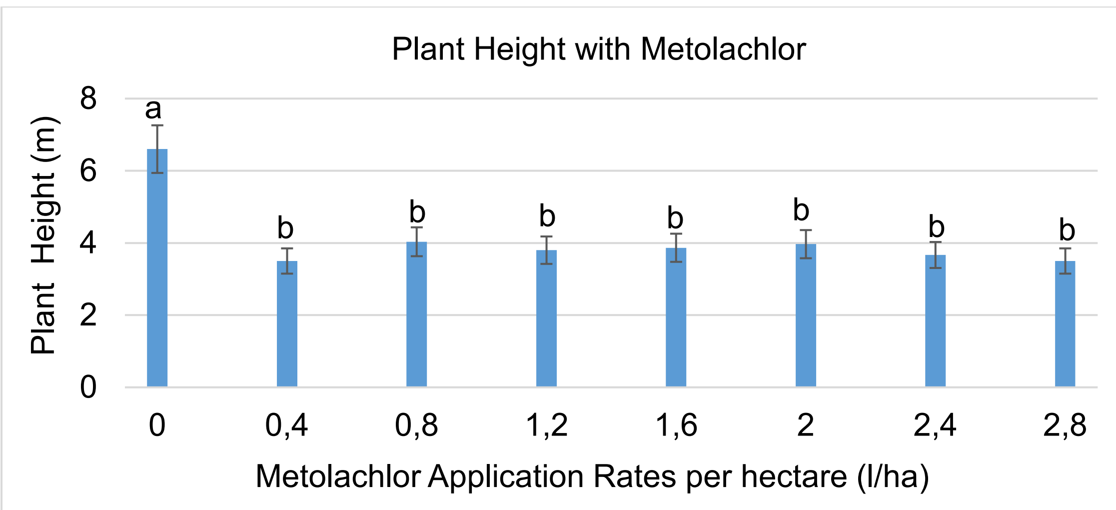

Figure 4.1.2: Graph of Plant height for Metolachlor application rates on Broccoli Hybrid Seedlings.

Figure 4.1.2 illustrates the plant height of seedlings that were measured, averaged over the 7 treatments plus untreated. Plant height was taken after 21 days of planting. The plant height results were assigned into two groups a and b. From Figure 4.1.2 above (Tukey's Studentized Range (HSD) Test) it is adequate to signify that the seven Metolachlor treatments had a significant effect on the plant height even though there were no significant differences among the seven Metolachlor rates from 0.4l/ha to 2.8l/ha with symbol “b”, it is evident that the control improves the plant height of broccoli denoted with symbol “a”.The other application rates did show no significance but the treatments do have some level of significance when compared with the control.

4.1.3: Root Length Sensitivity Of Metolachlor On Broccoli Hybrid Seedlings.

Table 4.1.3: ANOVA results for root length means of broccoli hybrid seedlings as affected by 7 application rates of soil applied Metolachlor plus the untreated.

Source	**DF**	**Sum of Squares**	**Root Length Mean**	**Mean Square**	**CV**	**F Value**	**Pr> F**
Metolachlor	7	196.79	7.46	28.11	6.51	118.79	<.0001

4.1.3.1: ANOVA: The obtained results illustrate that, there were significant differences in the root length by several application rates of Metolachlor when compared to the untreated trial, and a root length mean of 7.46m as shown above in Table 4.1.3.

4.1.3.2:Metolachlor Mean Separations For Root Length: Root length mean separation results for the 7 application rates of soil-applied Metolachlor including the untreated. Figure 4.1.3 below depicts the results obtained fromMetolachlor Tukey's Studentized Range (HSD) Test for root length.

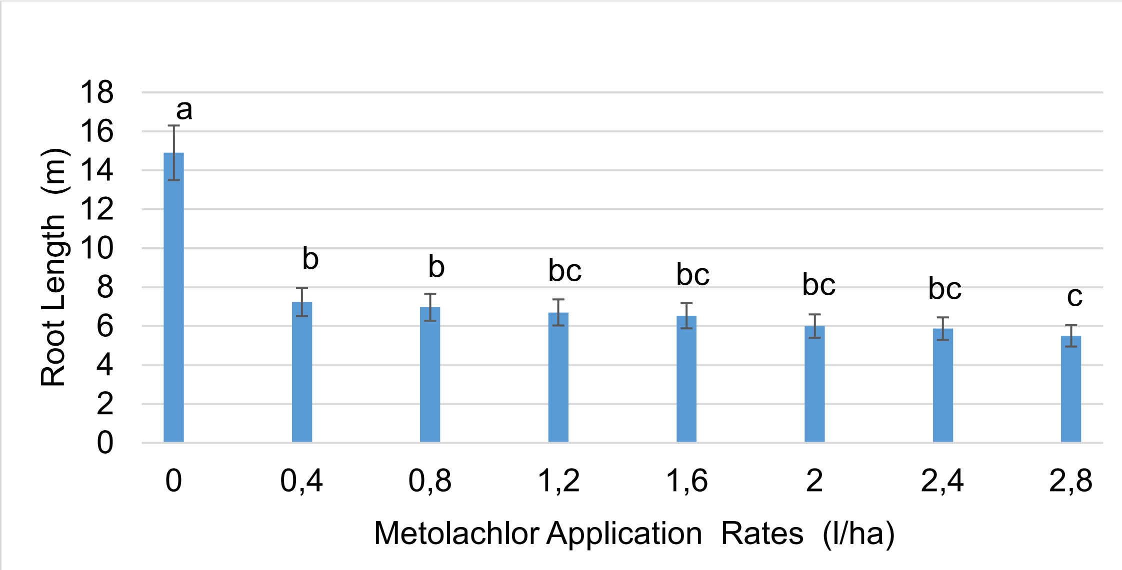

Figure 4.1.3: Graph of root length for Metolachlor application rates on Broccoli hybrid seedlings.

Figure 4.1.3 illustrates the root length of seedlings that were measured, averaged over the 7 treatments plus untreated. Root length was taken 21 days after planting. The results were allocated into three groups, a, b and c. From Figure 4.1.3 above (Tukey's Studentized Range (HSD) Test) it is satisfactory to signify that the seven metolachlor treatments have a significant effect on the root length, application rates0.4l/ha and 0.8l/ha denoted with “b” while rates 1.2l/ha, 1.6l/ha, 2.0l/ha and 2.4l/ha were not significant as denoted with symbol “bc”. The root length was seen to be related to the rates of application, the lower the rates the longer the root length as seen with rates 0.4 l/ha and 0.8 l/ha, and as the rates increased the length became shorter as seen from rates 1.2 l/ha to 2.4 l/ha symbol “bc” with the shortest root length being at the rates of 2.8 l/ha assigned symbol “c”. The root length was significant when compared with the untreated which is denoted as “a”.

4.1.4: Leaf Injury Tolerance Of Broccoli Hybrid Seedlings To Metolachlor.

Table 4.1.4: ANOVA results for Leaf Injury means of broccoli hybrid seedlings as affected by 7 application rates of soil applied Metolachlor plus the untreated.

Source	DF	Sum of Squares	Leaf injury Mean	Mean Square	CV	F Value	Pr> F
Metolachlor	7	3129.17	34.58	447.02	18.66	10.73	<.0001

4.1.4.1: ANOVA: The obtained results illustrate that, there were significant differences in the Leaf injury by several application rates of Metolachlor when compared to the untreated trial, and a leaf injury mean of 34.58% as shown above in Table 4.1.4.

4.1.4.2:Metolachlor Mean Separations For Leaf injury: Leaf injury mean separation results for the 7 application rates of soil-applied Metolachlor including the untreated. Figure 4.1.4 below depicts the results obtained from MetolachlorTukey'sStudentized Range (HSD) Test for leaf injury.

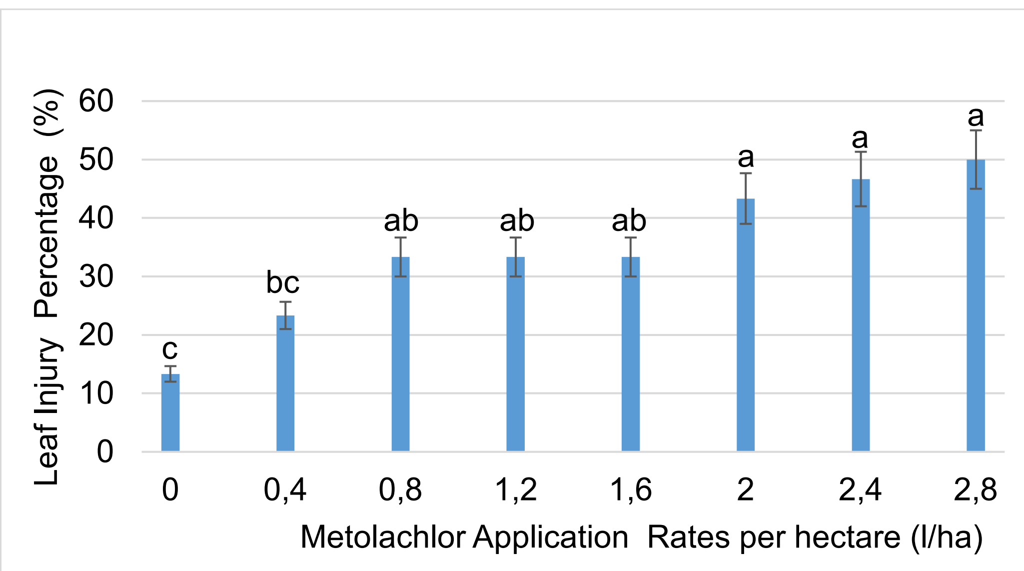

Figure 4.1.4: Graph of leaf injury for Metolachlor application rates on Broccoli

Figure 4.1.4 illustrates the visual leaf injury of seedlings that were measured, averaged over the 7 treatments plus untreated. The visual leaf injury was evaluated 21 days after planting. The results for the leaf injury of broccoli treatments were allocated into three groups, a, b, and c. According to Figure 4.1.4 above (Tukey's Studentized Range (HSD) Test), it is adequate to signify that Metolachlor influences visual leaf injury of broccoli, although there were no significant differences among three rates 0.8l/ha, 1.2l/ha, and 1.6l/ha which were denoted with symbol “ab”, also there was no significant difference amongst rates 2.0 l/ha,2.4l/ha and 2.8l/ha denoted with symbol “a” while rates 0.4 l/ha are significantly different with symbols “bc”. The control enhanced the visual leaf injury of broccoli with the symbol “c” having the least visual leaf injury. The visual leaf injury was significant when compared with the control which is denoted as “c”.

4.1.5: Sensitivity of Stunt count on Broccoli Hybrid Seedlings in Relation toMetolachlor Efficacy.

Table 4.1.5: ANOVA results for Stunt count means of broccoli hybrid seedlings as affected by 7 application rates of soil applied Metolachlor plus the untreated.

Source	DF	Sum of Squares	Stunt Count Mean	Mean Square	CV	F Value	Pr> F
Metolachlor	7	7495.83	40.42	1070.83	15.15	28.56	<.0001

4.1.5.1:ANOVA: The obtained results illustrate that, there were significant differences in the Stunt count by several application rates of Metolachlor when compared to the untreated trial, and a stunt count mean of 40.42% as shown above in Table 4.1.5.

4.1.5.2: Metolachlor Mean Separations For Stunt Count: Stunt count mean separation results for the 7 application rates of soil-applied Metolachlor including theuntreated.

Figure 4.1.5 below depicts the results obtained from MetolachlorTukey'sStudentized Range (HSD) Test for stunt count.

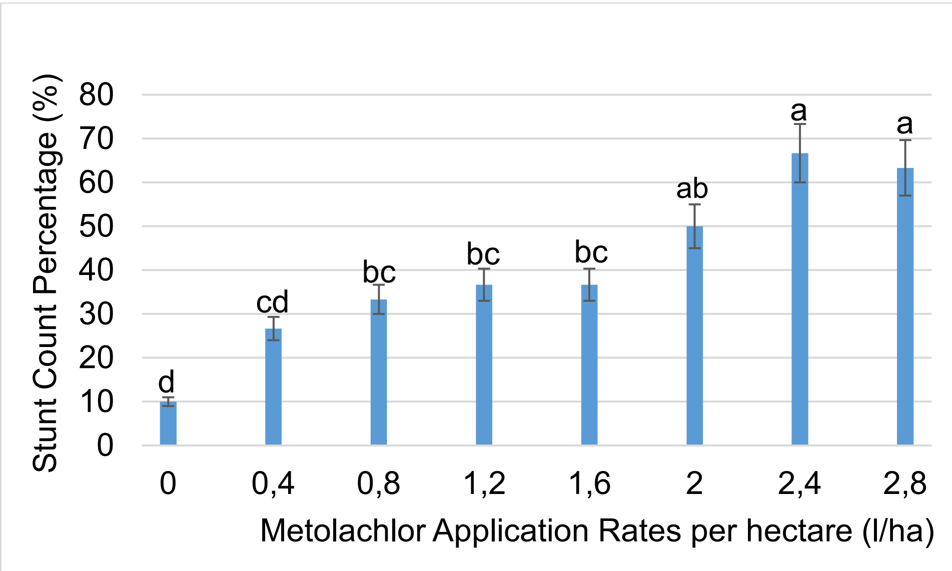

Figure 4.1.5: Graph of stunt count with percentage Metolachlor application rates on Broccoli.

Figure 4.1.5 illustrates the stunt count of seedlings averaged over the 7 treatments plus untreated. Stunt count was measured 21 days after planting. The results for stunt count of broccoli treatments were allocated into four groups, a, b, c and d. According to Figure 4.1.5 above (Tukey's Studentized Range (HSD) Test), it is enough to indicate that Metolachlor is sensitive in the stunt count of broccoli seedlings. There were no significant differences amongst the Metolachlor rates 0.8 l/ha, 1.2l/ha and 1.6l/ha as denoted with symbol “bc”, also rates at 2.4 l/ha and 2.8 l/ha had no significant difference as denoted with symbol “a”, rates 0.4l/ha and 2.0l/ha were both significantly different from the other five treatments as denoted with “cd” and “ab” respectively. The treatments of Metolachlor have a significant difference in stunt count of broccoli seedlings when compared with the untreated had the lowest stunt count and were denoted as “d”.

4.1.6: Necrosis Percentage Tolerance Of Metolachlor On Broccoli Hybrid Seedlings.

Table 4.1.6: ANOVA results for necrosis percentage means of broccoli hybrid seedlings as affected by 7 application rates of soil applied Metolachlor plus the untreated.

Source	DF	Sum of Squares	% Necrosis Mean	Mean Square	CV	F Value	Pr> F
Metolachlor	7	3962.50	40.42	566.07	14.28	16.98	<.0001

4.1.6.1:ANOVA: The obtained results illustrate that, there were significant differences in the Necrosis percentage by several application rates of Metolachlor when compared to the untreated trial, and a necrosis percentage means of 40.42% as shown above in Table 4.1.6

4.1.6.2:Metolachlor Mean Separations For Necrosis percentage: Necrosis percentage mean separation results for the 7 application rates of soil-applied Metolachlor including the untreated. Figure 4.1.6 below depicts the results obtained from Metolachlor Tukey's Studentized Range (HSD) Test for necrosis percentage.

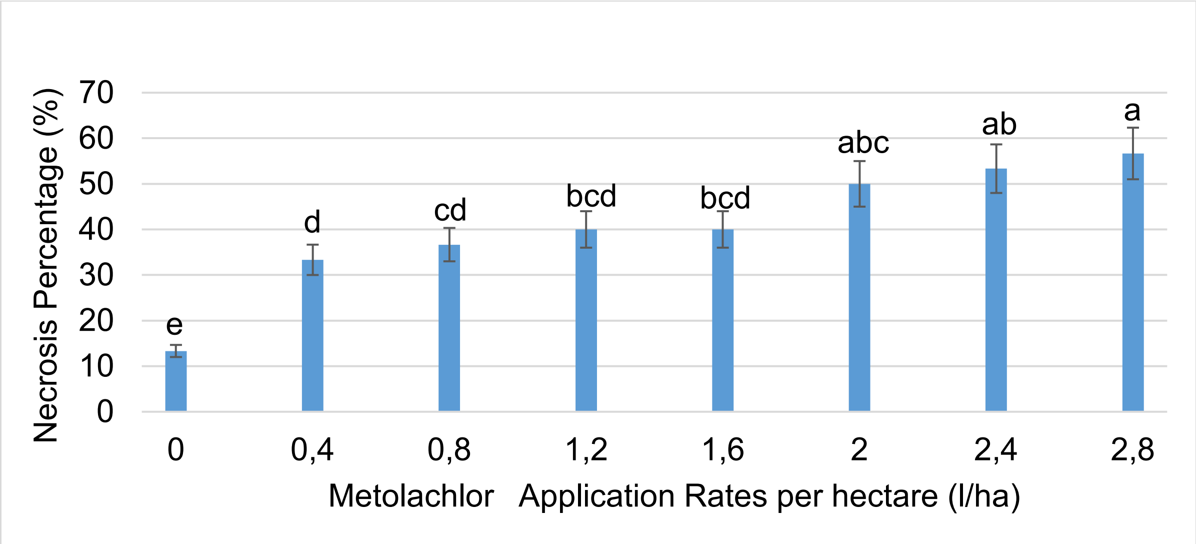

Figure 4.1.6: **Graph of necrosis percentage for Metolachlor application rates on Broccoli.**

Figure 4.1.6 illustrates the Necrotic percentage of seedlings averaged over the 7 treatments plus untreated. Percentage Necrosis was measured at 21 days after planting. The results were allocated into five groups, a, b, c, d, and e. According to figure 4.1.6 above (Tukey's Studentized Range (HSD) Test), it is sufficient to indicate that metolachlor has effects on the necrotic conditions of broccoli seedlings. There were no significant differences amongst the metolachlor rates 1.2 l/ha, and 1.6 l/ha, denoted with symbol “bcd”, while other treatment rates are significantly different with each other as denoted with different symbols “a”, “ab”, “abc” “cd” and “d” respectively. The treatments did show a significant difference when compared with the untreated, denoted with symbol “e”.

4.1.7: Influence Of Metolachlor On Days To Emergence of Broccoli Hybrid Seedlings.

Table 4.1.7: ANOVA results for days to emergence means of broccoli hybrid seedlings as affected by 7 application rates of soil applied Metolachlor plus the untreated.

Source	DF	Sum of Squares	Daysto Emergence Mean	Mean Square	CV	F Value	Pr> F
Metolachlor	7	10.67	4.50	1.52	6.42	18.29	<.0001

4.1.7.1:ANOVA: The obtained results illustrate that, there were significant differences in the days to emergence by several application rates of Metolachlor when compared to the untreated trial, and days to emergence means of 4.50days as shown above in Table 4.1.7

4.1.7.2:Metolachlor Mean Separations for Days to emergence: Days to emergence Mean separation results for the 7 application rates of soil-applied Metolachlor including the untreated. Figure 4.1.7 below depicts the results obtained from Metolachlor Tukey's Studentized Range (HSD) Test for days to emergence.

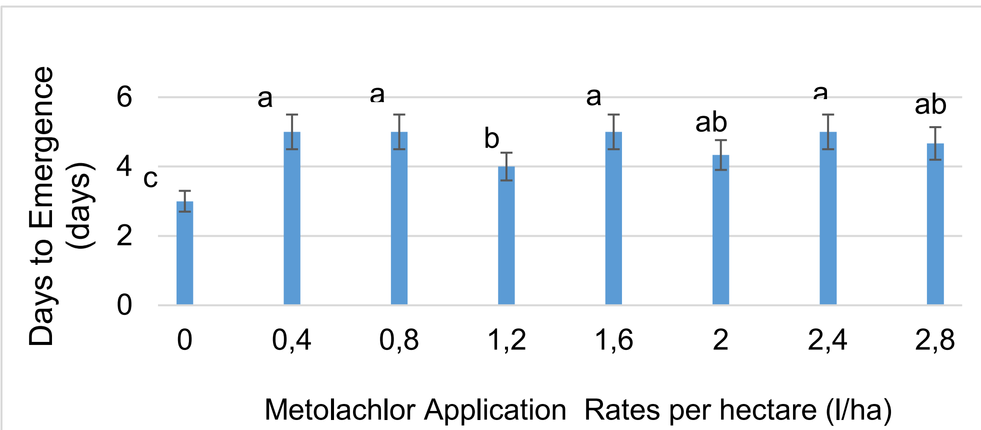

Figure 4.1.7: Graph of Days to Emergence for Metolachlor application rates on Broccoli.

Figure 4.1.7 illustrates the days to the emergence of seedlings that were recorded, averaged over the 7 treatments plus untreated. Days to emergence data was taken within 7 days from the date of planting. The results were allocated into 3 groups, a, b, and c. From the figure 4.1.7 above (Tukey's Studentized Range (HSD) Test) it is adequate to signify that the seven metolachlor treatments have a significant effect on the days to emergence, also there were slight significant differences among the seven metolachlor rates. The days to emergence was seen not to be significantly different amongst the four levels, (0.4l/ha, 0.8l/ha, 1.6l/ha and 2.4l/ha) as denoted with symbol “a”. Application at rates 2.0 l/ha and 2.8.l/ha as denoted with symbol “ab” had no significant difference whilst application rate 1.2l/ha is significantly different “b”. The days to emergence were significant when compared with the untreated which is denoted as “c”.

4.1.8:Germination Percentage Effect of Metolachlor On Broccoli Hybrid Seedlings.

Table 4.1.8: ANOVA results for germination percentage means of broccoli hybrid seedlings as affected by 7 application rates of soil-applied Metolachlor plus the untreated.

Source	DF	Sum of Squares	% Germination Mean	Mean Square	CV	F Value	Pr> F
Metolachlor	7	829.17	93.75	118.45	6.12	3.55	<.0.0169

4.1.8.1:ANOVA: The obtained results illustrate that, there were significant differences in the germination percentage by several application rates of Metolachlor when compared to the untreated trial, and germination means of 93.75% as shown above in Table 4.1.8

4.1.8.2:Metolachlor Mean Separations For Germination Percentage: Germination percentage Mean separation results for the 7 application rates of soil-appliedMetolachlorincluding the untreated. Figure 4.1.8 below depicts the results obtained from Metolachlor Tukey's Studentized Range (HSD) Test for germination percentage.

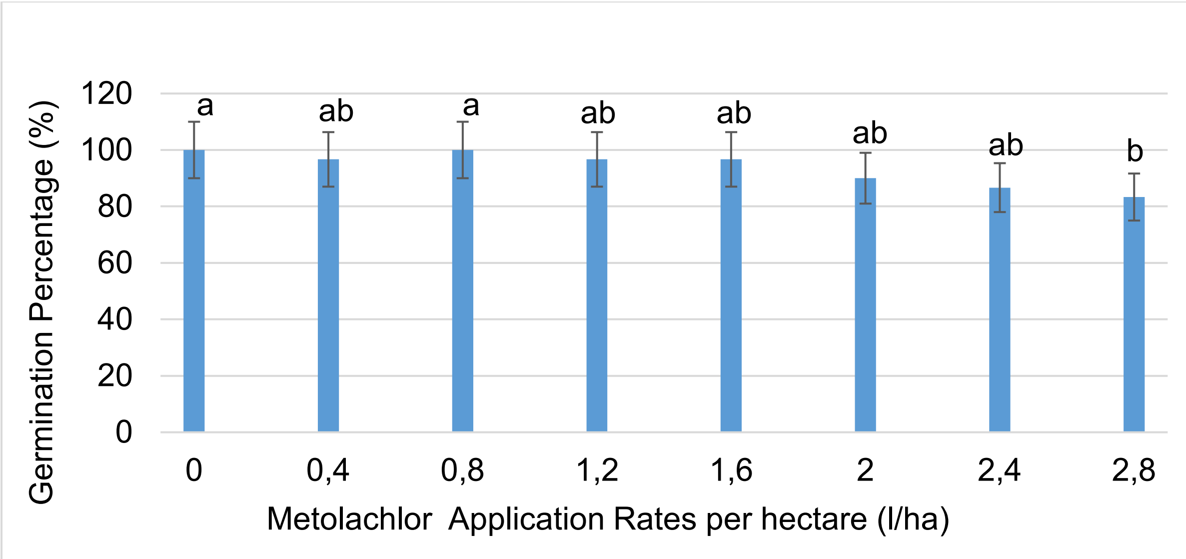

Figure 4.1.8: Graph of Germination PercentageforMetolachlor application rates on Broccoli.

Figure 4.1.8 illustrates the germination percentage of seedlings that were obtained, averaged over the 7 treatments plus untreated. The germination percentage was evaluated 7 days after planting. The results were allocated into two groups a and b. According to Figure 4.1.8 above (Tukey's Studentized Range (HSD) Test), it is apparent to indicate that metolachlor has an influence on the germination percentage of broccoli. There were two groups of no significant difference across the seven treatments as rates 0.4l/ha,1.2l/ha,1.6l/ha,2.0l/ha, and 2.4l/ha were not significantly different denoted with symbol “ab” whilst rates 2.8 l/ha was significantly different denoted with symbol “b”. It is indicated that the control and application rate at 0.4l/ha were both not significantly different as denoted with symbol “a”, it was apparent that the treatments do have some level of significance when compared with both the untreated and application rates 0.8l/ha denoted with symbol “a”.

4.2: Efficacy Of Halosulfuron Herbicide On Shoot And Root Plant Growth Parameters Of Broccoli Hybrid Seedlings.

4.2.1: Effect of Halosulfuron on Emergence percentageof Broccoli Hybrid Seedlings.

Table 4.2.1: ANOVA results for emergence percentage means of broccoli hybrid seedlings as affected by 7 application rates of soil appliedHalosulfuron plus the untreated.

Source	DF	Sum of Squares	% Emergence Mean	Mean Square	CV	F Value	Pr> F
Halosulfuron	7	1129.17	95.42	161.31	9.32	2.04	<.0.1130

4.2.1.1: ANOVA: The obtained results illustratethat, there were no significant differences in emergence percentage by several application rates of halosulfuron when compared to the untreated trial, also with an emergence percentage mean of 95.42% as shown above in Table 4.2.1

4.2.1.2:HalosulfuronMean Separations For Emergence Percentage: Emergence percentage Mean separation results for the 7 application rates of soil-appliedHalosulfuron plus the untreated. Figure 4.2.1 below depicts the results obtained from HalosulfuronTukey'sStudentized Range (HSD) Test for emergence percentage.

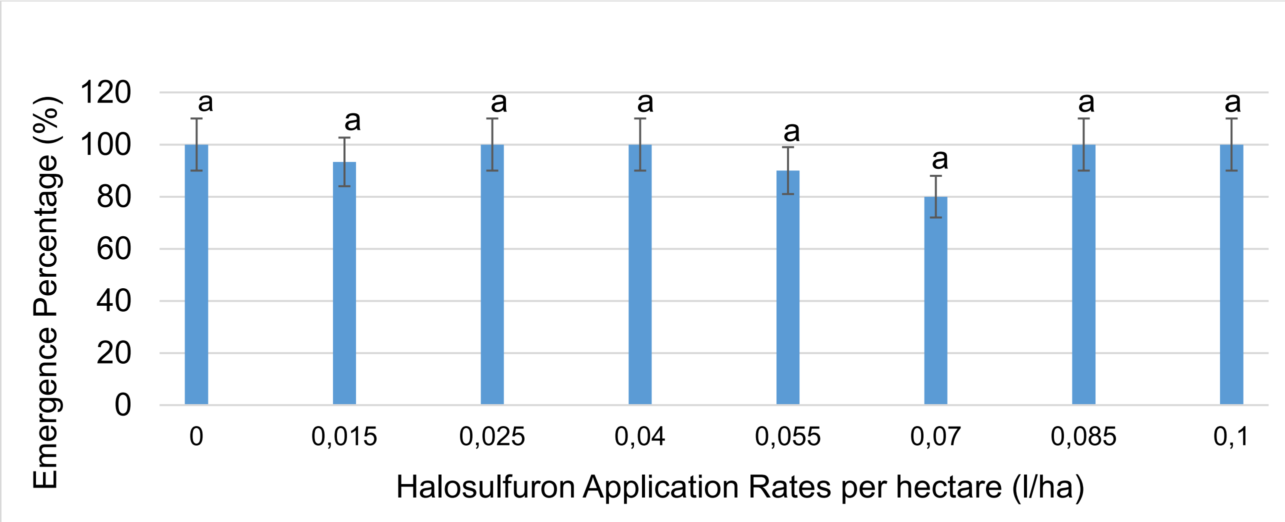

Figure 4.2.1: **Graph of Emergence Percentage for Halosulfuron application rates on Broccoli**

Figure 4.2.1 illustrates the percentage of seedlings that emerged, averaged over the 7 treatments plus control. Emergence was evaluated 7 days after planting. They were assigned to a single group a. According to figure 4.2.1 above (Tukey's Studentized Range (HSD) Test), it is sufficient to indicate that Halosulfuron has no influence in the emergence of broccoli. There was no significant difference between the seven treatments and the control; they are all denoted with the symbol “a”. It is apparent that the treatments have no level of significance when compared with the untreated.

4.2.2: Influence of Halosulfuron on Plant Height of BroccoliHybrid Seedlings.

Table 4.2.2: ANOVA results for plant height means of broccoli hybrid seedlings as affected by 7 application rates of soil appliedHalosulfuron plus the untreated.

Source	DF	Sum of Squares	Plant height Mean	Mean Square	CV	F Value	Pr> F

Halosulfuron	7	49.66	8.07	7.09	5.82	32.19	<.0001

4.2.2.1: ANOVA: The obtained results illustrate that, there were **significant** differences in the plant height by several application rates of Halosulfuron when compared to the untreated trial, and a plant height mean of 8.07m as shown above in Table 4.2.2

4.2.2.2:HalosulfuronMean Separations for Plant height: Plant height Mean separation results for the 7 application rates of soil-applied Halosulfuron including the untreated. Figure 4.2.2 below depicts the results obtained from HalosulfuronTukey'sStudentized Range (HSD) Test for plant height.

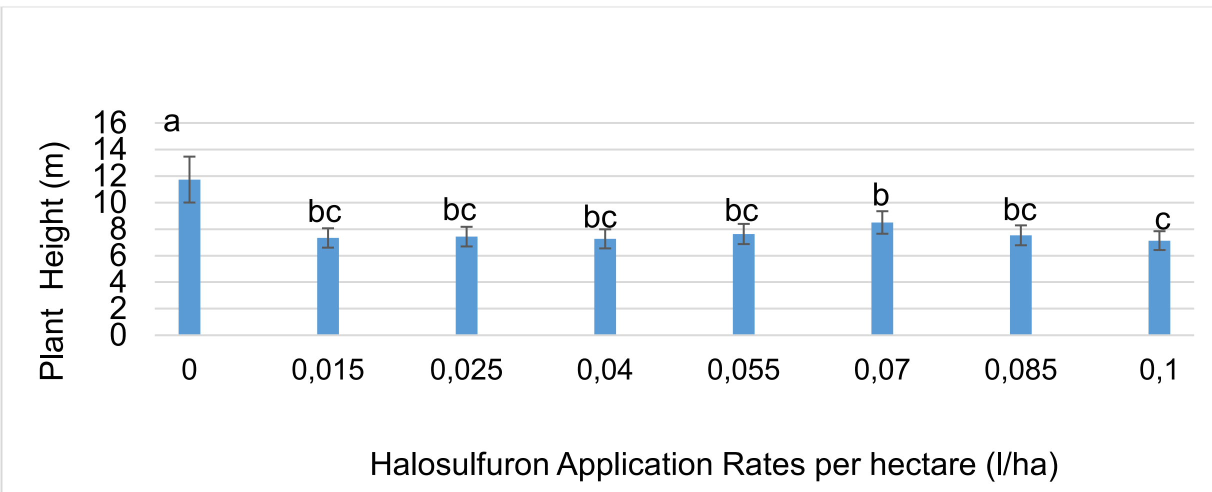

Figure 4.2.2: Graph of Plant height for Halosulfuron application rates on Broccoli

Figure 4.2.2 illustrates the plant height of seedlings that were measured, averaged over the 7 treatments plus control. Plant height was evaluated 21 days after planting. The results were assigned into three groups a, b, and c. According to figure 4.2.2 above (Tukey's Studentized Range (HSD) Test), it is adequate to signify that Halosulfuron has an influence on plant height of broccoli, although there were no significant differences among the five Halosulfuron rates 0.015l/ha, 0.025l/ha, 0.040l/ha,0.055l/ha and 0.085l/ha which were denoted with symbol “bc”, while rates 0.070l/ha and 0.10 l/ha are significantly different with symbols “b” and “c” respectively. The treatments had a level of significance on the plant height when compared with the untreated denoted with symbol “a”.

4.2.3: Root Length Tolerance of Halosulfuron On Broccoli HybridSeedlings.

Table 4.2.3: ANOVA results for root length means of broccoli hybrid seedlings as affected by 7 application rates of soil appliedHalosulfuron plus the untreated.

Source	**DF**	**Sum of Squares**	**Root length Mean**	**Mean Square**	**CV**	**F Value**	**Pr> F**
Halosulfuron	7	49.66	12.07	7.09	3.89	32.19	<.0001

4.2.3.1: ANOVA: The obtained results illustrate that, there were significant differences in the root length by several application rates of Halosulfuron when compared to the untreated trial, and a root length mean of 12.07m as shown above in Table 4.2.3.

4.2.3.2:HalosulfuronMean Separations For Root Length: Root length Mean separation results for the 7 application rates of soil-appliedHalosulfuron including the untreated. Figure 4.2.3 below depicts the results obtained from HalosulfuronTukey'sStudentized Range (HSD) Test for plant height.

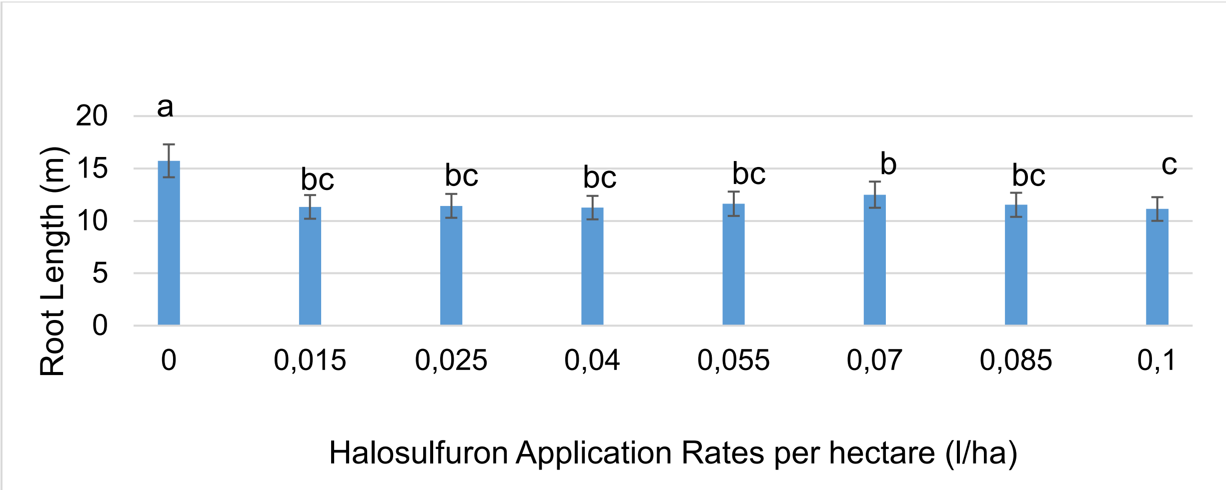

Figure 4.2.3: Graph of root length for Halosulfuron application rates on Broccoli seedlings

Figure 4.2.3 illustrates the root length of seedlings that was measured, averaged over the 7 treatments plus control. The root length was evaluated 21 days after planting. The results were assigned into three groups, a, b, and c. According to Figure 4.2.3above (Tukey's Studentized Range (HSD) Test) it is satisfactory to signify that halosulfuron has an influence in root length of broccoli, although there were no significant differences among the five halosulfuron rates 0.015l/ha, 0.025l/ha, 0.040l/ha,0.055l/ha and 0.085l/ha which were denoted with symbol “bc”, while rates 0.070l/ha and 0.10 l/ha are significantly different with symbols “b” and “c” respectively. The treatments had a significant difference on the root length of broccoli seedlings when compared with the untreated denoted with symbol “a”.

4.2.4: Leaf Injury Sensitivity Of Halosulfuron On Broccoli Hybrid Seedlings.

Table 4.2.4: ANOVA results for leaf injury means of broccoli hybrid seedlings as affected by 7 application rates of soil appliedHalosulfuron plus the untreated.

Source	DF	Sum of Squares	Leaf Injury Mean	Mean Square	CV	F Value	Pr> F
Halosulfuron	7	429.17	10.42	61.31	39.19	3.68	<.0.0147

4.2.4.1: ANOVA: The obtained results illustrate that, there were significant differences in the leaf injury by several application rates of Halosulfuron when compared to the untreated trial, and a leaf injury mean of 10.42% as shown above in Table 4.2.4.

4.2.4.2:Halosulfuron Mean Separations For Leaf injury: Leaf injury Mean separation results for the 7 application rates of soil-appliedHalosulfuron including the untreated. Figure 4.2.4 below depicts the results obtained from HalosulfuronTukey'sStudentized Range (HSD) Test for leaf injury.

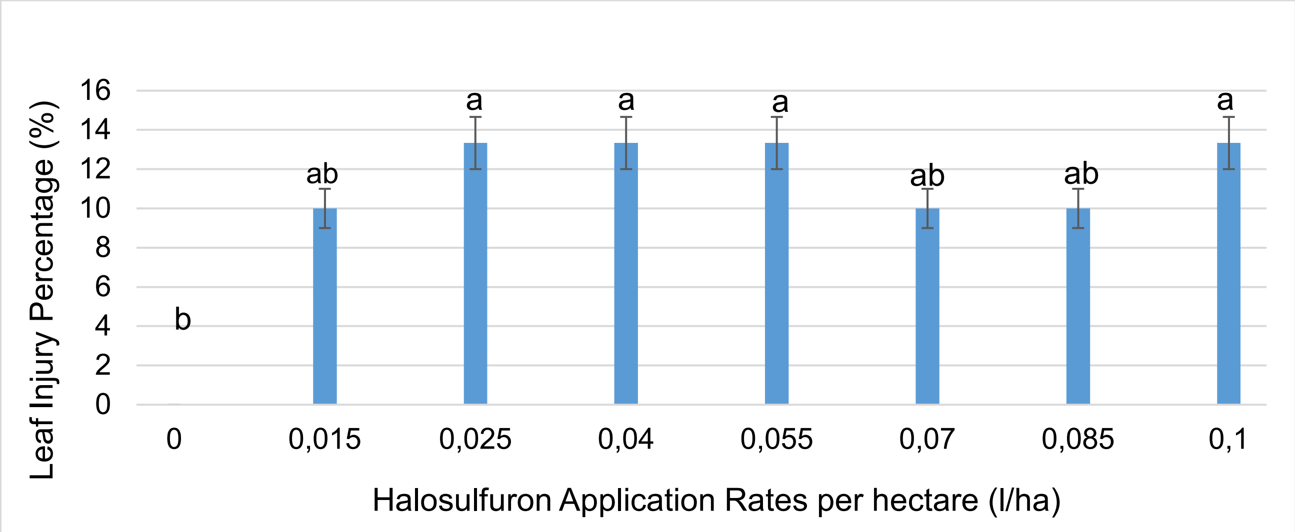

Figure 4.2.4: Graph of Leaf InjuryforHalosulfuron application rates on Broccoli Seedlings

Figure 4.2.4 illustrates the visual leaf injury percentage of seedlings that were measured, averaged over the 7 treatments plus control. The leaf injury was evaluated 21 days after planting. The results for leaf injury of broccoli treatments were assigned into three groups, a, b, and c. According to figure 4.2.4 above (Tukey's Studentized Range (HSD) Test), it is adequate to signify that Halosulfuron is sensitive in visual leaf injury of broccoli. There were two groups of no significant difference across the seven treatments as rates 0.015l/ha, 0.070l/h and 0.085l/ha were not significantly different denoted with symbol “ab” while rates 0.025l/ha, 0.040l/ha, 0.055l/ha and 0.10 l/ha were not also significantly different denoted with symbol “a”, The treatments had a significant difference in the leaf injury of broccoli seedlings when compared with the untreated denoted with symbol “b”.

4.2.5: Sensitivity Of Halosulfuron On Stunt Count Of Broccoli Hybrid Seedlings.

Table 4.2.5: ANOVA results for stunt count means of broccoli hybrid seedlings as affected by 7 application rates of soil appliedHalosulfuron plus the untreated.

Source	DF	Sum of Squares	Stunt Count Mean	Mean Square	CV	F Value	Pr> F
Halosulfuron	7	533.33	11.67	76.19	42.86	3.05	<.0.0307

4.2.5.1: ANOVA: The obtained results illustrate that, there were significant differences in the stunt count by several application rates of Halosulfuron when compared to the untreated trial, and a stunt count mean of 11.67% as shown above in Table 4.2.5.

4.2.5.2:HalosulfuronMean Separations For Stunt Count: Stunt count Mean separation results for the 7 application rates of soil-appliedHalosulfuron including the untreated. Figure 4.2.5 below depicts the results obtained from HalosulfuronTukey'sStudentized Range (HSD) Test for stunt count.

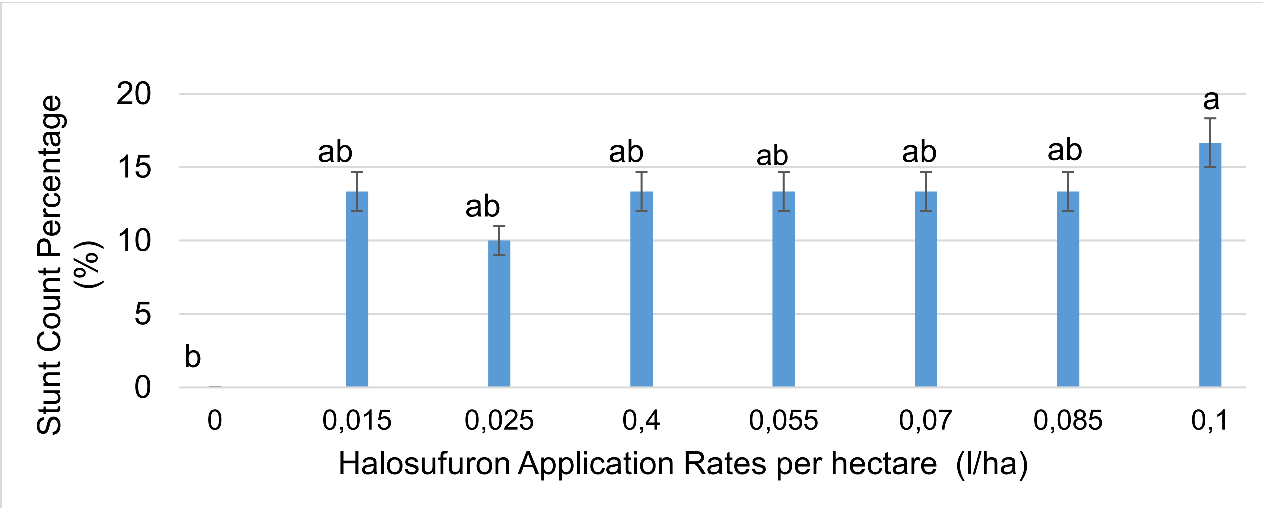

Figure 4.2.5: Graph of Stunt count for Halosulfuron application rates on Broccoli Seedlings

Figure 4.2.5 illustrates the stunt count of seedlings that were obtained, averaged over the 7 treatments plus control. The stunt count was evaluated 21 days after planting. The results were assigned into two groups, a and b. According to figure 4.2.5 above (Tukey's Studentized Range (HSD) Test), it is obvious to signify that halosulfuron is sensitive in stunt count of broccoli. There were two groups of no significant difference across the seven treatments as rates 0.015l/ha, 0.025l/ha, 0.040l/ha, 0.055l/ha 0.070l/ha and 0.085l/ha were not significantly different denoted with symbol "ab" whilst rates 0.10 l/ha was significantly different denoted with symbol "a". The treatment does have some level of significance on the stunt count of broccoli seedlings when compared with the untreated denoted with symbol "b".

4.2.6: Necrosis Percentage Effects Of Halosulfuron On Broccoli Hybrid Seedlings.

Table 4.2.6: ANOVA results for necrosis percentage means of broccoli hybrid seedlings as affected by 7 application rates of soil appliedHalosulfuron plus the untreated.

Source	DF	Sum of Squares	Necrosis % Mean	Mean Square	CV	F Value	Pr> F
Halosulfuron	7	450.00	10.83	64.29	42.13	3.09	<.0.0294

4.2.6.1: ANOVA: The obtained results illustrate that, there were significant differences in necrosis percentage by several application rates of Halosulfuron when compared to the untreated trial, also with a necrosis percentage mean of 10.83% as shown above in Table 4.2.6

4.2.6.2:HalosulfuronMean Separations For Necrosis Percentage: Necrosis percentage Mean separation results for the 7 application rates of soil-appliedHalosulfuron including the untreated. Figure 4.2.6 below depicts the results obtained from HalosulfuronTukey'sStudentized Range (HSD) Test for necrosis percentage.

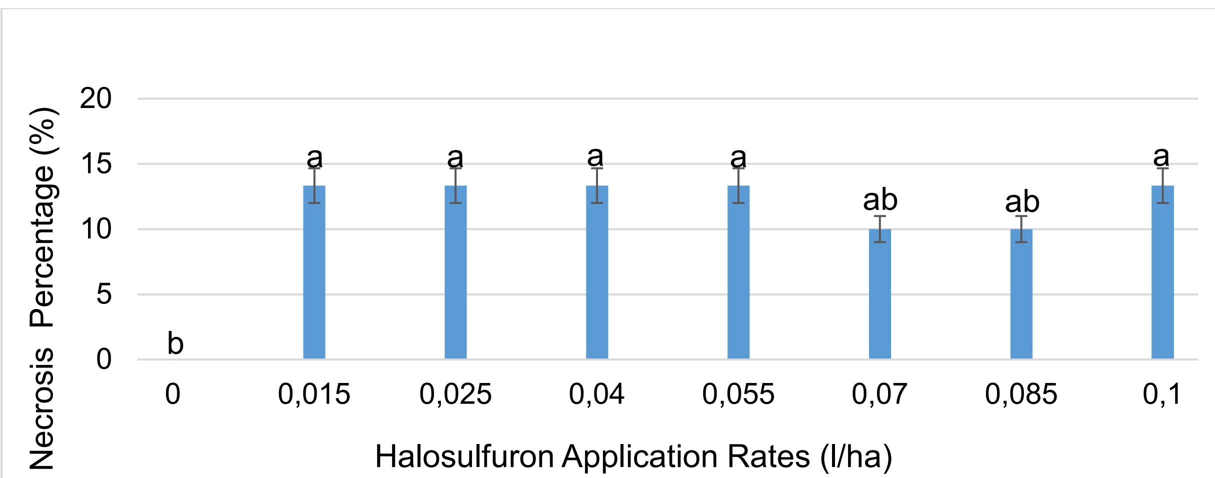

Figure 4.2.6: Graph of necrosis Percentage for Halosulfuron application rates on Broccoli seedling.

Figure 4.2.6 illustrates the necrosis percentage of seedlings that were measured, averaged over the 7 treatments plus control. The leaf injury was evaluated 21 days after planting. The results for necrosis percentage of broccoli treatments were assigned into two groups, a and b. According to Figure 4.2.6 above (Tukey's Studentized Range (HSD) Test), it is sufficient to signify that Halosulfuron is sensitive in the necrosis of broccoli. There were two groups of no significant difference across the seven treatments as rates 0.070l/ha and 0.085l/ha were not significantly different denoted with symbol “ab” whereas rates 0.015l/ha, 0.025l/ha, 0.040l/ha, 0.055l/ha and 0.10 l/ha were not also significantly different denoted with symbol “a”. The treatments do have some level of significance on necrosis percentage when compared with the untreated denoted with symbol “b”.

4.2.7: Effect Of Halosulfuron On The Days To Emergence Of Broccoli Hybrid Seedlings.

Table 4.2.7: ANOVA results for days to emergence means of broccoli hybrid seedlings as affected by 7 application rates of soil appliedHalosulfuron plus the untreated.

Source	DF	Sum of Squares	Days to Emergence Mean	Mean Square	CV	F Value	Pr> F
Halosulfuron	7	2.96	3.38	0.42	19.13	1.01	<.0.4577

4.2.7.1: ANOVA: The obtained results illustrate that, there were no significant differences in days to emergence by several application rates of Halosulfuron when compared to the untreated trial, alsowith days to emergence mean of 3.38days as shown above in Table 4.2.7

4.2.7.2:HalosulfuronMean Separations For Days To Emergence: Days to emergence Mean separation results for the 7 application rates of soil-applied Halosulfuronincluding the untreated. Figure 4.2.7 below depicts the results obtained from HalosulfuronTukey'sStudentized Range (HSD) Test for days to emergence.

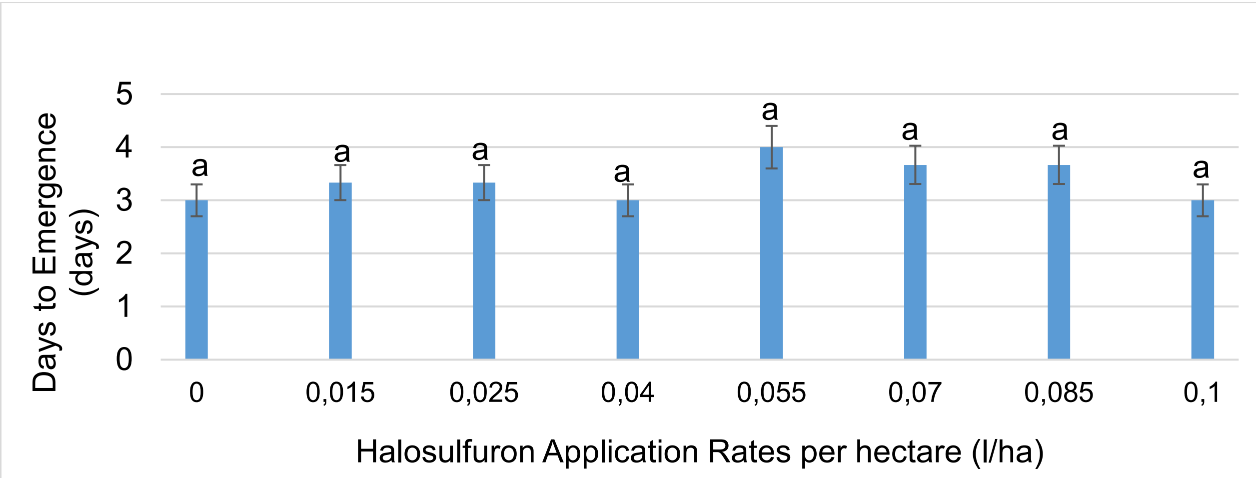

Figure 4.2.7: Graph of days to Emergence for Halosulfuron application rates on Broccoli Seedlings.

Figure 4.2.7 illustrates the days to the emergence of seedlings that were obtained, averaged over the 7 treatments plus control. The days to emergence were evaluated within 7 days after the date of planting. The results for days to the emergence of broccoli treatments were assigned to one group alone a. According to figure 4.2.7 above (Tukey's Studentized Range (HSD) Test), it is evident to signify that Halosulfuron has no effects on days to the emergence of broccoli. There was no significant difference between the seven treatments and the control; they are all denoted with the symbol “a”. The treatments have no level of significance on days to emergence when compared with the untreated.

4.2.8: Germination Percentage Efficacy of BroccoliHybrid Seedlings to Halosulfuron.

Table 4.2.8: ANOVA results for germination percentage means of broccoli hybrid seedlings as affected by 7 application rates of soil appliedHalosulfuron plus the untreated.

Source	DF	Sum of Squares	%Germination Mean	Mean Square	CV	F Value	Pr> F
Halosulfuron	7	583.33	94.17	83.33	12.45	0.61	<.0.7428

4.2.8.1: ANOVA: The obtained results illustratethat, there were no significant differences in germination percentage by several application rates of halosulfuron when compared to the untreated trial, also with a germination percentage mean of 94.17% as shown above in Table 4.2.8

4.2.8.2:HalosulfuronMean Separations For Germination Percentage: Germination percentage Mean separation results for the 7 application rates of soil-appliedHalosulfuron plus the untreated. Figure 4.2.8 below depicts the results obtained from HalosulfuronTukey'sStudentized Range (HSD) Test for germination percentage.

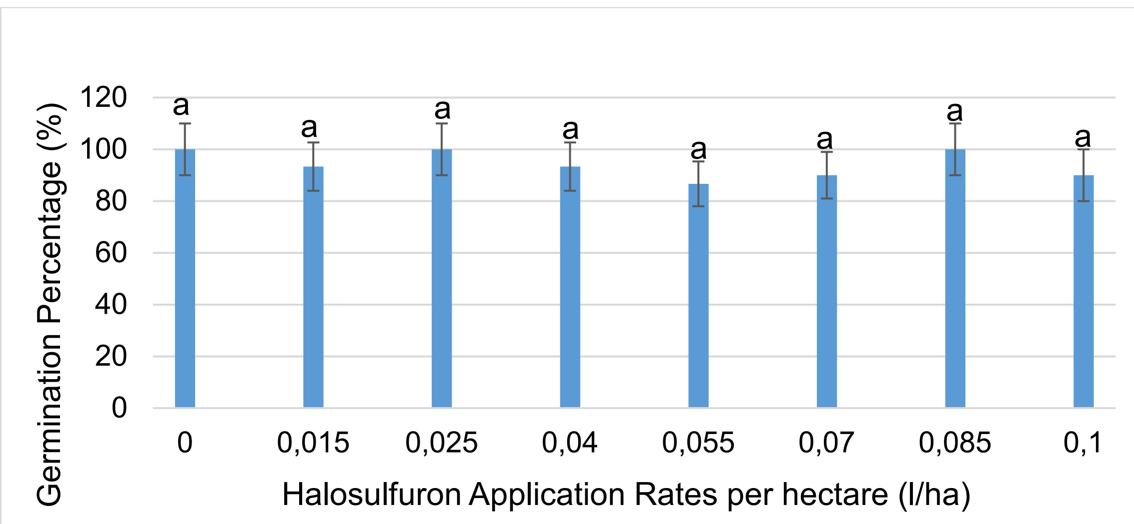

Figure 4.2.8: Graph of Germination Percentage for Halosulfuron application rates on Broccoli Seedlings.

Figure 4.2.8 illustrates the germination percentage of seedlings that were measured, averaged over the 7 treatments plus control. The germination percentage was evaluated 7 days after planting. The results were allocated to one group alone a. According to Figure 4.2.8 above (Tukey's Studentized Range (HSD) Test), it is evident to point out that halosulfuron has no effects on the germination percentage of broccoli. There was no significant difference between the seven treatments and the untreated; they are all denoted with the symbol “a”. The treatments have no level of significance on the germination percentage when compared with the control.

4.3: Influence of Clomazone on Shoot and Root Plant Growth Parameters of Broccoli Hybrid Seedlings.

4.3.1 Sensitivity Of Clomazone On Emergence Percentage Of Broccoli Hybrid Seedlings.

Table 4.3.1: ANOVA results for emergence percentage means of broccoli hybrid seedlings as affected by 7 application rates of soil-applied clomazone plus the untreated.

Source	DF	Sum of Squares	% Emergence Mean	Mean Square	CV	F Value	Pr> F
Clomazone	7	9600.00	75.00	1371.43	20.00	6.10	<.0.0014

4.3.1.1: ANOVA: The obtained results illustrate that, there were significant differences in the emergence percentage by several application rates of clomazone when compared to the untreated trial, and an emergence percentage mean of 75% as shown above in Table 4.3.1

4.3.1.2:Clomazone Mean Separations for Emergence percentage: Emergence percentage Mean separation results for the 7 application rates of soil-applied Clomazone including the untreated. Figure 4.3.1 below depicts the results obtained from ClomazoneTukey'sStudentized Range (HSD) Test for emergence percentage.

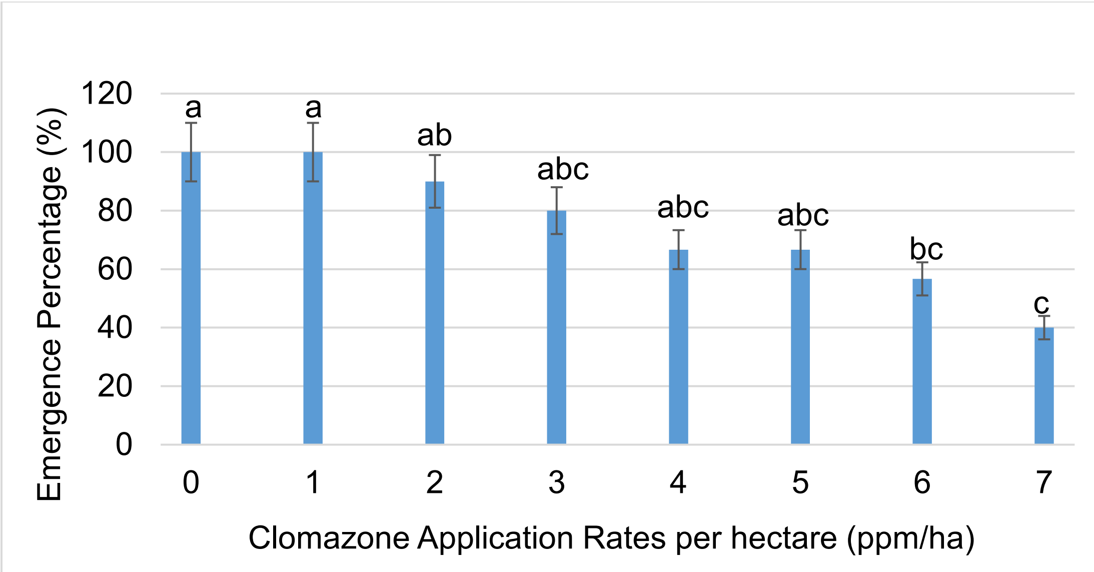

Figure 4.3.1: Graphof Emergence Percentage for Clomazone application rates on Broccoli Seedlings.

Figure 4.3.1 illustrates the percentage of seedlings that emerged, averaged over the 7 treatments plus control. Emergence was evaluated 7 days after planting. The results for the emergence of broccoli treatments were allocated into three groups, a,b, and c. According to figure 4.3.1 above (Tukey's Studentized Range (HSD) Test), it is adequate to signify that clomazone is sensitive in the emergence of broccoli seedlings. There were no significant differences amongst the clomazone rates 3ppm l/ha, 4ppm l/ha, and 5ppm l/ha denoted with symbol “abc”, but were significantly different with other application rates, which were 2ppm l/ha assigned symbol “ab”, rates 6ppm l/ha denoted with symbol “bc” and rates 7ppm l/ha assigned with symbol “c”. Application rates of 1ppm l/ha showed no significant difference with the control as both were denoted with the symbol “a”. The untreated and application rates 1ppm l/ha enhanced the emergence percentage of broccoli with the symbol “a” having a 100%emergence. The treatments of clomazone have a significant difference in the emergence percentage of broccoli seedlings with exception of 1ppm application rate.

4.3.2: Influence of Clomazone in the Plant Height ofBroccoli Hybrid Seedlings.

Table 4.3.2: ANOVA results for plant height means of broccoli hybrid seedlings as affected by 7 application rates of soil-applied clomazone plus the untreated.

Source	DF	Sum of Squares	Plant height Mean	Mean Square	CV	F Value	Pr> F
Clomazone	7	64.54	2.44	9.22	17.22	51.94	<.0001

4.3.2.1: ANOVA: The obtained results illustrate that, there were significant differences in the plant height by several application rates of Clomazone when compared to the untreated trial, and a plant height mean of 2.44m as shown above in Table 4.3.2

4.3.2.2:Clomazone Mean Separations For Plant Height: Plant height Mean separation results for the 7 application rates of soil-applied Clomazone including the untreated. Figure 4.3.2 below depicts the results obtained from Clomazone Tukey's Studentized Range (HSD) Test for plant height.

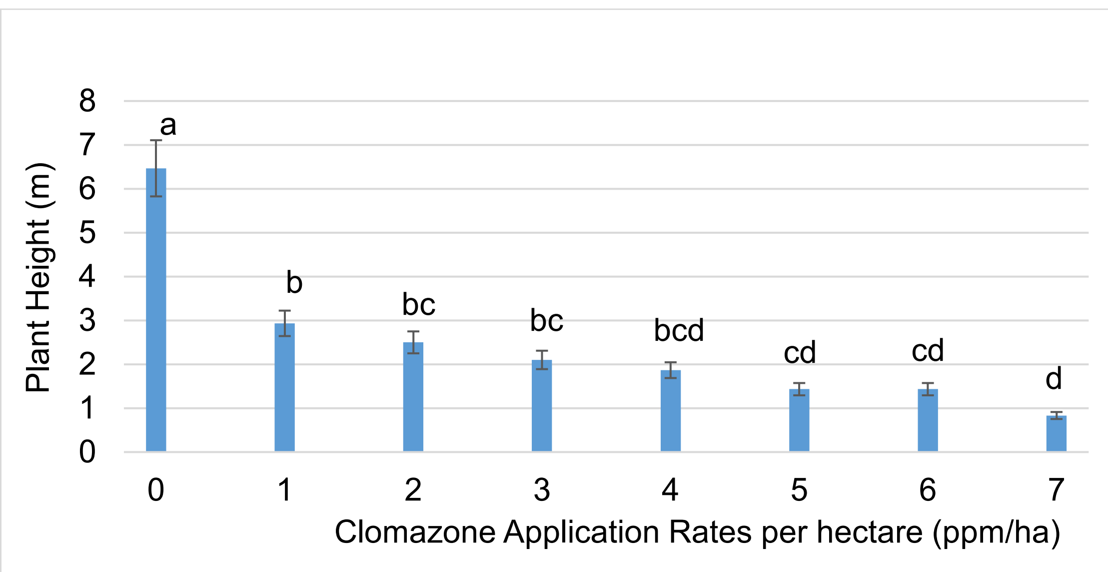

Figure 4.3.2: Graphof Plant height for Clomazone application rates on Broccoli Seedlings.

Figure 4.3.2 illustrates the plant height of seedlings averaged over the 7 treatments plus control. Plant height was measured 21 days after planting. The results were allocated into four groups, a, b, c, and d. According to figure 4.3.2 above (Tukey's Studentized Range (HSD) Test), it is adequate to signify that clomazone is sensitive in the plant height of broccoli seedlings. There were no significant differences amongst the clomazone rates 2ppm l/ha and 3ppm l/ha as denoted with symbol “bc”, also rates at 5ppm l/ha and 6ppm l/ha had no significant difference as denoted with symbol “cd”, rates 1ppml/ha, 4ppm l/ha, and 7ppm l/ha were all significantly different from the other four treatments as denoted with “b”, “bcd” and “d” respectively. it is obvious that the treatments of clomazone have a significant difference in plant height of broccoli seedlings when compared with the untreated denoted with “a”.

4.3.3: Root Length Effects Of Clomazone On Broccoli Hybrid Seedlings.

Table 4.3.3: ANOVA results for root length means of broccoli hybrid seedlings as affected by 7 application rates of soil-applied clomazone plus the untreated.

Source	DF	Sum of Squares	Root length Mean	Mean Square	CV	F Value	Pr> F
Clomazone	7	228.54	5.24	32.65	9.66	127.62	<.0001

4.3.3.1: ANOVA: The obtained results illustrate that, there were significant differences in the root length by several application rates of Clomazone when compared to the untreated trial, and a root length meanof 5.24m as shown above in Table 4.3.3

4.3.3.2:Clomazone Mean Separations For Root Length: Root length Mean separation results for the 7 application rates of soil-applied Clomazone including the untreated. Figure 4.3.3 below depicts the results obtained from Clomazone Tukey's Studentized Range (HSD) Test for root length.

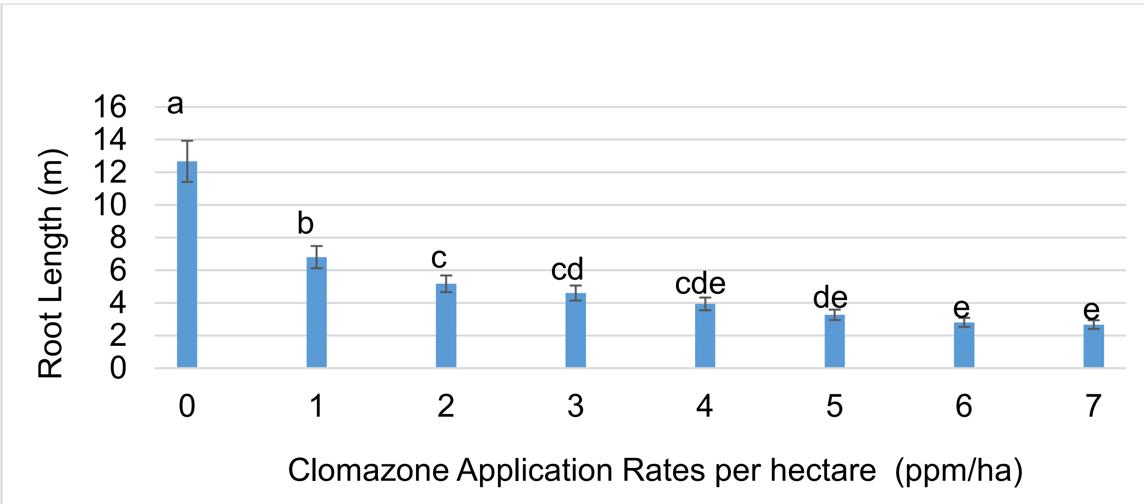

Figure 4.3.3: Graphof Root length for Clomazone application rates on Broccoli seedlings.

Figure 4.3.3 illustrates the root length of seedlings averaged over the 7 treatments plus control. Root length was measured 21 days after planting. The results for root length of broccoli treatments were allocated into five groups, a, b, c, d, and e. According to figure 4.3.3 above (Tukey's Studentized Range (HSD) Test), it is enough to signify that clomazone has effects on the root length of broccoli seedlings. There were no significant differences amongst the clomazone rates 6ppm l/ha, and 7ppm l/ha, denoted with symbol “e”, while other rates are significantly different from each other as denoted with different symbols “b”, “c”, “cd” “cde” and “de” respectively. The treatments did show a significant difference in the root length when compared with the untreated, denoted with the symbol “a”.

4.3.4: Leaf Injury Sensitivity Of BrocoliHybrid Seedlings To Clomazone.

Table 4.3.4: ANOVA results for leaf injury means of broccoli hybrid seedlings as affected by 7 application rates of soilappliedclomazone plus the untreated.

Source	DF	Sum of Squares	Leaf injury Mean	Mean Square	CV	F Value	Pr> F
Clomazone	7	8062.50	35.42	1151.79	16.30	34.55	<.0001

4.3.4.1: ANOVA: The obtained results illustrate that, there were significant differences in the leaf injury by several application rates of Clomazone when compared to the untreated trial, and a leaf injury mean of 35.42% as shown above in Table 4.3.4

4.3.4.2:Clomazone Mean Separations For Leaf injury: Leaf injury Mean separation results for the 7 application rates of soil-applied Clomazone plus the untreated. Figure 4.3.4 below depicts the results obtained from Clomazone Tukey's Studentized Range (HSD) Test for leaf injury.

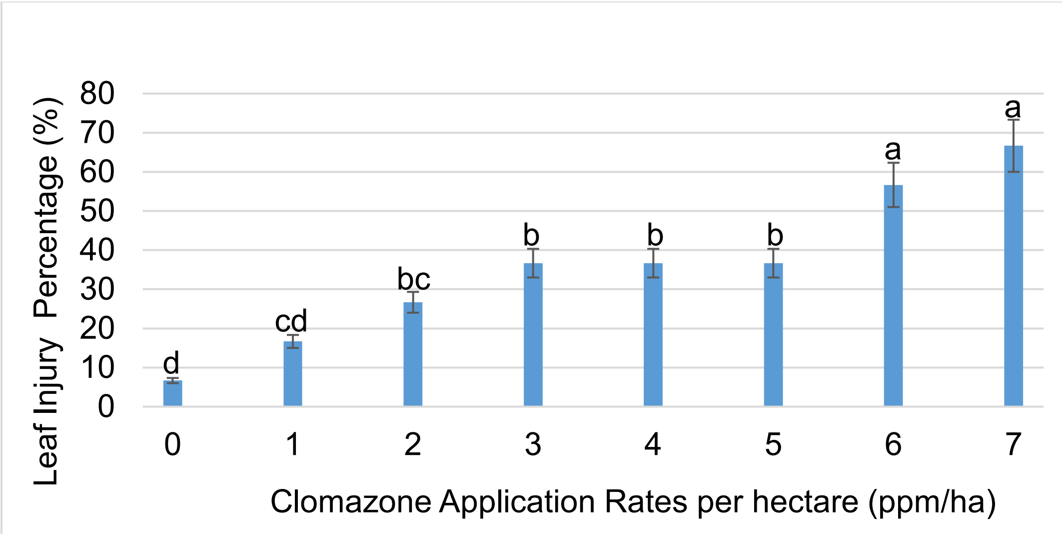

Figure 4.3.4: GraphofClomazone application rates and Broccoli on Leaf injury.

Figure 4.3.4 illustrates the visual leaf injury of seedlings averaged over the 7 treatments plus control. Visual leaf injury was measured 21 days after planting.The results for leaf injury of broccoli treatments were allocated into four groups, a,b,c, and d. According to figure 4.3.4 above (Tukey's Studentized Range (HSD) Test), it is sufficient to signify that clomazone is sensitive in leaf injury of broccoli seedlings. There were no significant differences amongst the clomazone rates 3ppm l/ha, 4ppm l/ha, and 5ppm l/ha as denoted with symbol “b”, also rates at 6ppm l/ha and 7ppm l/ha had no significant difference as denoted with symbol “a”, rates 1ppml/ ha, and 2ppm l/ha were both significantly different from the other four treatments as denoted with “cd”, and “bc” respectively. The treatments of clomazone have a significant difference in leaf injury of broccoli seedlings when compared with the untreated denoted with symbol “d”.

4.3.5: Effect Of Clomazone In Stunt Count Of Broccoli Hybrid Seedlings.

Table 4.3.5: ANOVA results for stunt count means of broccoli hybrid seedlings as affected by 7 application rates of soil-applied clomazone plus the untreated.

Source	DF	Sum of Squares	Stunt count Mean	Mean Square	CV	F Value	Pr> F
Clomazone	7	14995.83	45.42	2142.26	13.48	57.13	<.0001

4.3.5.1: ANOVA: The obtained results illustrate that, there were significant differences in the stunt count by several application rates of Clomazone when compared to the untreated trial, and a stunt count mean of 45.42% as shown above in Table 4.3.5

4.3.5.2:Clomazone Mean Separations For Stunt Count: Stunt count Mean separation results for the 7 application rates of soil-applied Clomazone including the untreated. Figure 4.3.5 below depicts the results obtained from Clomazone Tukey's Studentized Range (HSD) Test for Stunt count.

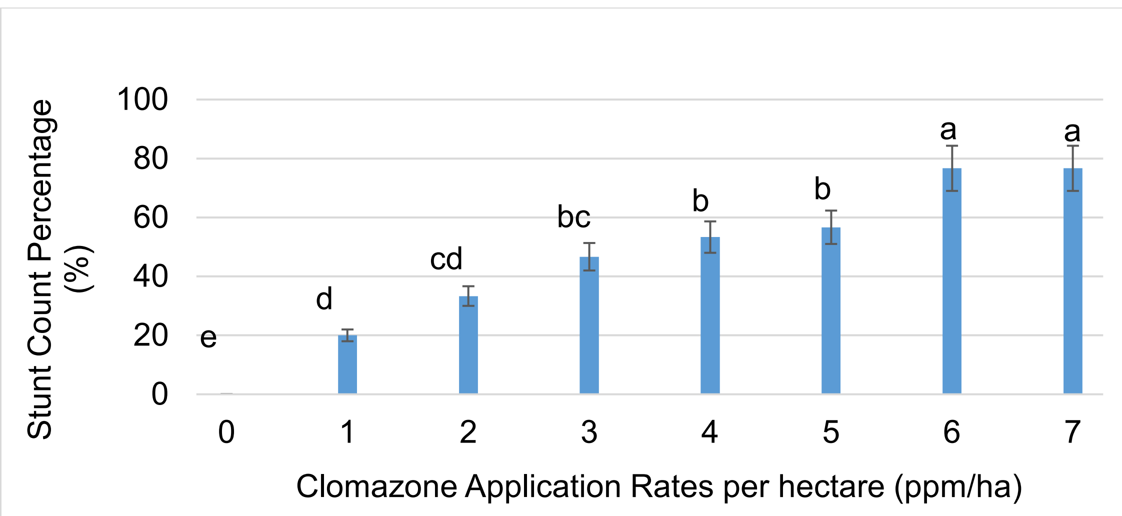

Figure 4.3.5: Graphof Stunt count for Clomazone application rates on Broccoli seedlings

Figure 4.3.5 illustrates the stunted seedlings averaged over the 7 treatments plus control. Stunt count was obtained 21 days after planting. The results for stunt count of broccoli treatments were allocated into five groups, a, b, c, d, and e. According to figure 4.3.5 above (Tukey's Studentized Range (HSD) Test), it is enough to indicate that clomazone is sensitive in the stunt count of broccoli seedlings. There were no significant differences amongst the clomazone rates 4ppm l/ha and 5ppm l/ha as denoted with symbol “b”, also rates at 6ppm l/ha and 7ppm l/ha had no significant difference as denoted with symbol “a”, rates 1ppml/ha, 2ppm l/ha, and 3ppm l/ha were all significantly different from the other four treatments as denoted with “d”, “cd” and “bc” respectively. The treatments of clomazone have a significant difference in stunt count of broccoli seedlings when compared with the untreated denoted with “e”.

4.3.6: Necrosis Percentage Tolerance Of Clomazone On Broccoli Hybrid Seedlings.

Table 4.3.6: ANOVA results for necrosis percentage means of broccoli hybrid seedlings as affected by 7 application rates of soil-applied clomazone plus the untreated.

Source	DF	Sum of Squares	Necrosis Percentage Mean	Mean Square	CV	F Value	Pr> F
Clomazone	7	15695.83	56.25	2242.26	9.60	76.88	<.0001

4.3.6.1:ANOVA: The obtained results illustrate that, there were significant differences in the necrosis percentage by several application rates of Clomazone when compared to the untreated trial, and a necrosis percentage mean of 56% as shown above in Table 4.3.6

4.3.6.2:Clomazone Mean Separations For Necrosis Percentage: Necrosis percentage Mean separation results for the 7 application rates of soil-applied Clomazone including the untreated. Figure 4.3.6 below depicts the results obtained from Clomazone Tukey's Studentized Range (HSD) Test for necrosis percentage.

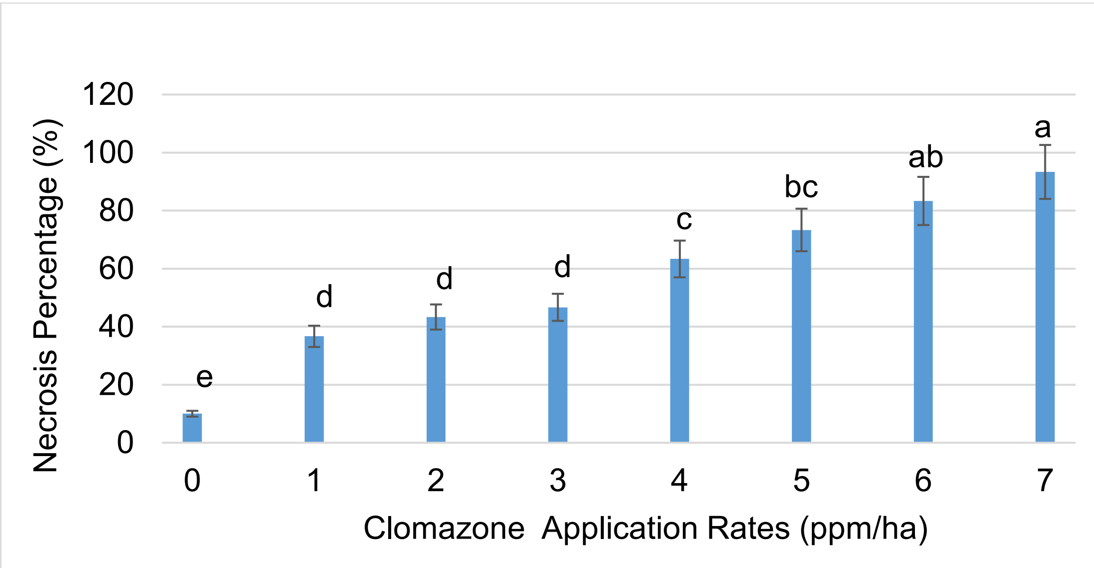

Figure 4.3.6: GraphofClomazone application rates and Broccoli on Necrosis Percentage.

Figure 4.3.6 illustrates the necrosis percentage of seedlings that were calculated, averaged over the 7 treatments plus control. Necrosis percentage data was taken 21 days after planting. The results were allocated into five groups, a, b, c, d, and e. From figure 4.3.6 above (Tukey's Studentized Range (HSD) Test) it is adequate to indicate that the seven clomazone treatments have a significant effect on the necrosis percentage, also there were significant differences among the seven Clomazone rates. The necrosis percentage was seen to be directly related to the rates of application, as the Clomazone rates the increases the necrosis percentage increased as well, as seen with rates 1ppm l/ha, 2ppm l/ha, and 3ppm l/ha as denoted with symbol “d”, while 4ppml/ha, 5ppm l/ha, 6ppm l/ha and 7ppm l/ha rates denoted with “c ”, “bc”, “ab” and “a” respectively which showed higher level of necrosis percentage. The treatments had a significant difference in the necrosis percentage of the broccoli seedlings when compared with the untreated which is denoted as “e”.

4.3.7: Influence Of Clomazone On Days To Emergence Of Broccoli Hybrid Seedlings.

Table 4.3.7: ANOVA results for days to emergence means of broccoli hybrid seedlings as affected by 7 application rates of soilappliedclomazone plus the untreated.

Source	DF	Sum of Squares	Days to Emerg Mean	Mean Square	CV	F Value	Pr> F
Clomazone	7	22.63	4.79	3.23	14.13	7.05	<.0.0006

4.3.7.1: ANOVA: The obtained results illustrate that, there were significant differences in the days to emergence by several application rates of Clomazone when compared to the untreated trial, and days to emergence mean of 4.79days as shown above in Table 4.3.7

4.3.7.2:Clomazone Mean Separations For Days To Emergence: Days to emergence Mean separation results for the 7 application rates of soil-applied Clomazone includingthe untreated. Figure 4.3.7 below depicts the results obtained from Clomazone Tukey's Studentized Range (HSD) Test for days to emergence.

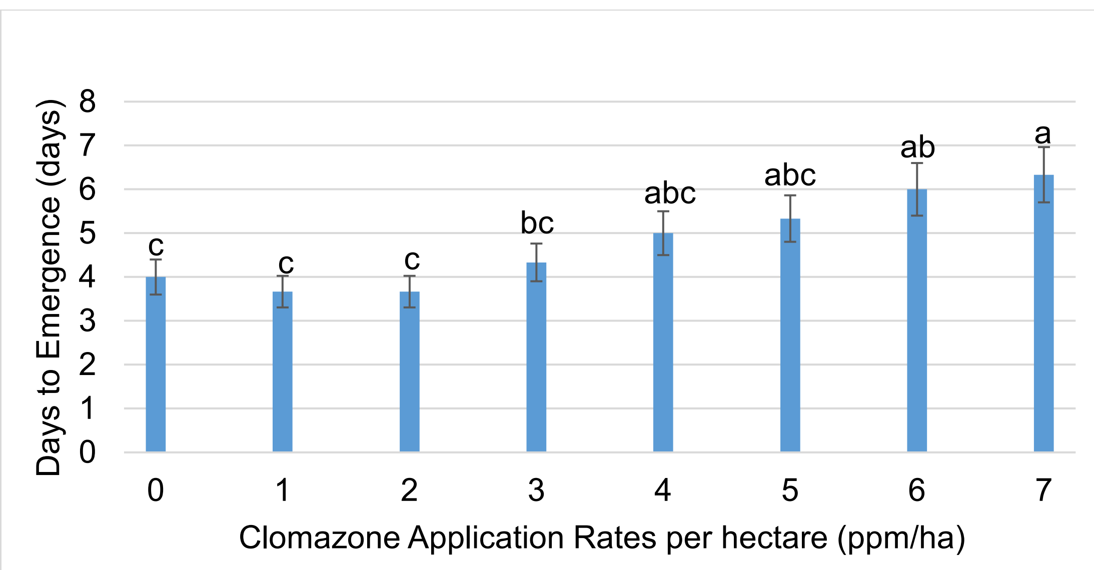

Figure 4.3.7: Graphof Days to Emergence for Clomazone application rates on Broccoli seedlings.

Figure 4.3.7 illustrates the days of the emergence of seedlings averaged over the 7 treatments plus control. Days to emergence was recorded within 7 days after planting. The results for days to the emergence of broccoli treatments were assigned into three groups, a, b, and c. According to figure 4.3.7 above (Tukey's Studentized Range (HSD) Test), it is enough to indicate that clomazone is sensitive in days to the emergence of broccoli seedlings. There were no significant differences amongst the clomazone rates 4ppm l/ha, and 5ppm l/ha, denoted with symbol “abc”, while rates 3ppm l/ ha, 6ppm l/ha and 7ppm l/ha were significantly different with other application rates, as allocated symbol “bc”, “ab” and “a” respectively. Application rates of 1ppm l/ha and 2ppm l/ha showed no significant difference with the untreated as denoted with symbol “a”. The treatments of clomazone have a significant difference in broccoli seedlings with exception of 1ppm and 2ppm l/ha application rates when compared with the untreated.

4.3.8: Efficacy of Clomazone on Germination of Broccoli Hybrid Seedlings

Table 4.3.8: ANOVA results for germination percentage means of broccoli hybrid seedlings as affected by 7 application rates of soil-applied clomazone plus the untreated.

Source	DF	Sum of Squares	%Germination Mean	Mean Square	CV	F Value	Pr> F
Clomazone	7	11316.67	70.83	1616.67	15.25	13.86	<.0001

4.3.8.1: ANOVA: The obtained results illustrate the results showed that, there were significant differences in the germination percentage by several application rates of Clomazone when compared to the untreated trial, and a germination percentage mean of 70.83% as shown above in Table 4.3.8

4.3.8.2:Clomazone Mean Separations For Germination Percentage: Germination percentage Mean separation results for the 7 application rates of soil-applied Clomazone including the untreated. Figure 4.3.8 below depicts the results obtained from Clomazone Tukey's Studentized Range (HSD) Test for germination percentage.

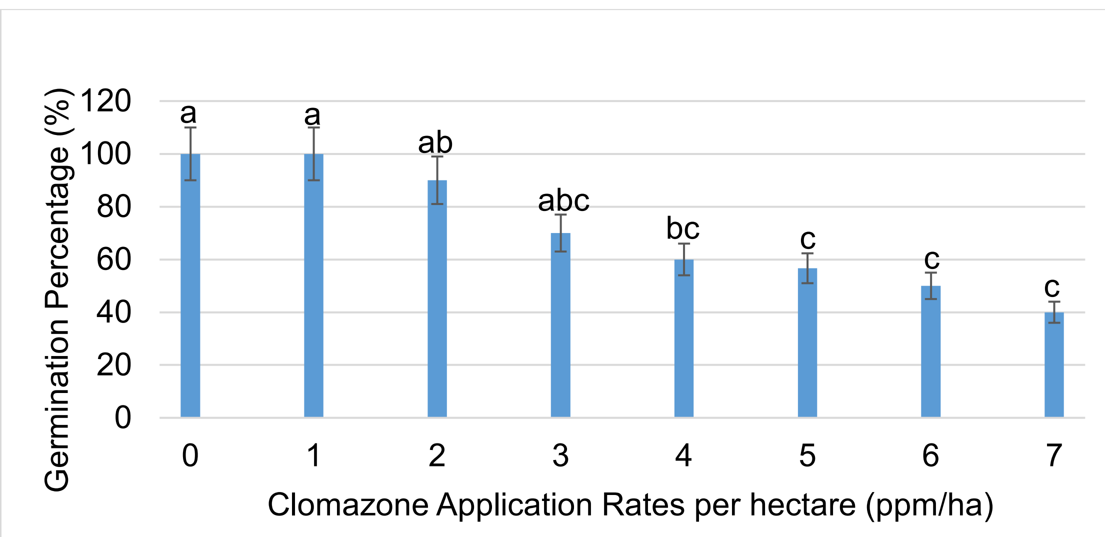

Figure 4.3.8: Graphof Germination percentage for Clomazone application rates on Broccoli seedlings.

Figure 4.3.8 illustrates the germination percentage of seedlings averaged over the 7 treatments plus control. Germination percentage was obtained within 7 days after planting. The results for germination percentage of broccoli treatments were assigned into three groups, a, b, and c. According to figure 4.3.8 above (Tukey's Studentized Range (HSD) Test), it is adequate to signify that clomazone has effects on the germination percentage of broccoli seedlings. There were no significant differences amongst the clomazone rates 5ppm l/ha,6ppm l/ha, and 7ppm l/ha, denoted with symbol “c”, also rates 2ppm l/ha, 3ppm l/ha and 4ppm l/ha were significantly different with other application rates, as assigned symbol “bc”, “abc” and “bc” respectively. The treatments of clomazone have a significant difference in germination percentage of broccoli seedlings with exception of 1ppml/ha application rates when compared with the untreated denoted with symbol “a”.

4.4: Sensitivity Of Oxadiazon On Shoot And Root Plant Growth Parameters On Broccoli Hybrid Seedlings.

4.4.1: Influence Of Oxadiazon On Emergence Percentage Of Broccoli Hybrid Seedlings

Table 4.4.1: ANOVA results for emergence percentage means of broccoli hybrid seedlings as affected by 7 application rates of soil applied Oxadiazon plus the untreated.

Source	DF	Sum of Squares	% Emergence Mean	Mean Square	CV	F Value	Pr> F
Oxadiazon	7	7595.83	72.08	1085.12	16.99	7.23	<.0005

4.4.1.1: ANOVA: The obtained results illustrate that, there were significant differences in the emergence percentage by several application rates of Oxadiazon when compared to the untreated trial, and an emergence percentage mean of 72.08% as shown above in Table 4.4.1.

4.4.1.2:Oxadiazon Mean Separations For Emergence Percentage: Emergence percentage mean separation results for the 7 application rates of soil-applied Oxadiazon including the untreated. Figure 4.4.1 below depicts the results obtained from Oxadiazon Tukey's Studentized Range (HSD) Test for emergence percentage.

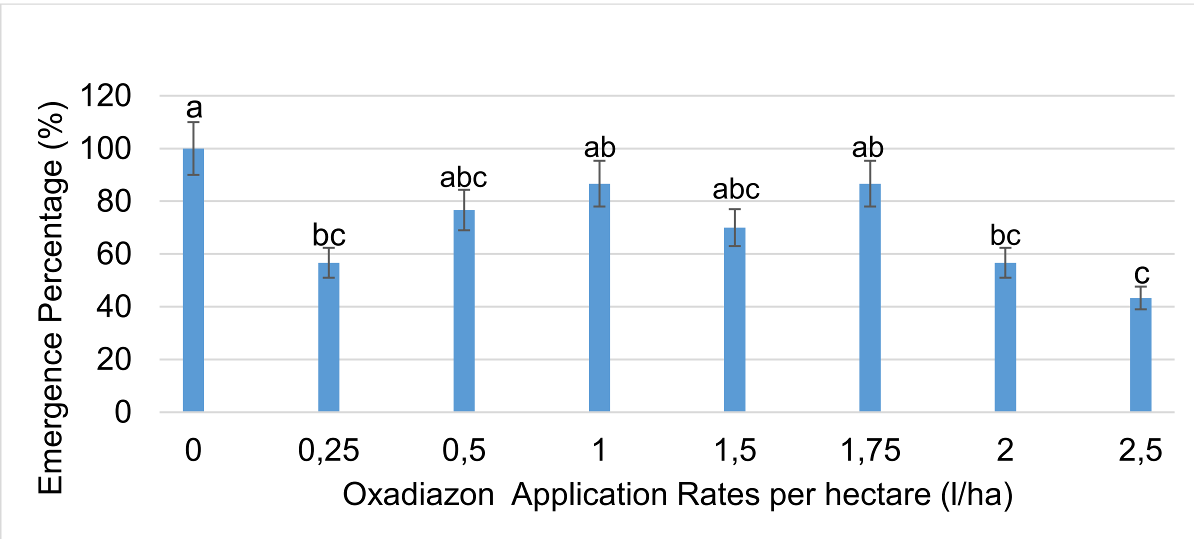

Figure 4.4.1: Graph of Emergence Percentage for Oxadiazon application rates on Broccoli seedlings.

Figure 4.4.1 illustrates the percentage of seedlings that emerged, averaged over the 7 treatments plus control. Emergence was evaluated 7 days after planting. The results for the emergence of broccoli treatments were allocated into three groups, a, b, and c. According to figure 4.4.1 above (Tukey's Studentized Range (HSD) Test), it is adequate to signify that oxadiazon influences the emergence of broccoli, although there were no significant differences among the two Oxadiazon rates 0.5 l/ha, and 1.5l/ha, assigned with symbol "abc" while rates 1.0 l/ha and 1.75l/ha showed no significant difference, noted with symbol "ab", also rates 0.25l/ha and 2.0l/ha showed no significant difference noted with the symbol "bc", and rate 2.5l/ha shows a significant difference denoted with the symbol "c", it is evident that the control enhanced the emergence percentage of broccoli with the symbol "a" having a 100% emergence. The results obtained show a level of a significant difference when compared with the untreated denoted with symbol "a".

4.4.2: Oxadiazon Efficacy On Plant Height of Broccoli Hybrid Seedlings.

Table 4.4.2: ANOVA results for plant height means of broccoli hybrid seedlings as affected by 7 application rates of soil applied Oxadiazon plus the untreated.

Source	DF	Sum of Squares	Plant height Mean	Mean Square	CV	F Value	Pr> F
Oxadiazon	7	47.44	3.90	6.78	6.49	105.62	<.0001

4.4.2.1: ANOVA: The obtained results illustrate that, there were significant differences in the plant height by several application rates of Oxadiazon when compared to the untreated trial, and a plant height mean of 3.90m as shown above in Table 4.4.2

4.4.2.2:Oxadiazon Mean Separations For Plant Height: Plant height mean separation results for the 7 application rates of soil-applied Oxadiazon plus the untreated. Figure 4.4.2 below depicts the results obtained from Oxadiazon Tukey's Studentized Range (HSD) Test for plant height.

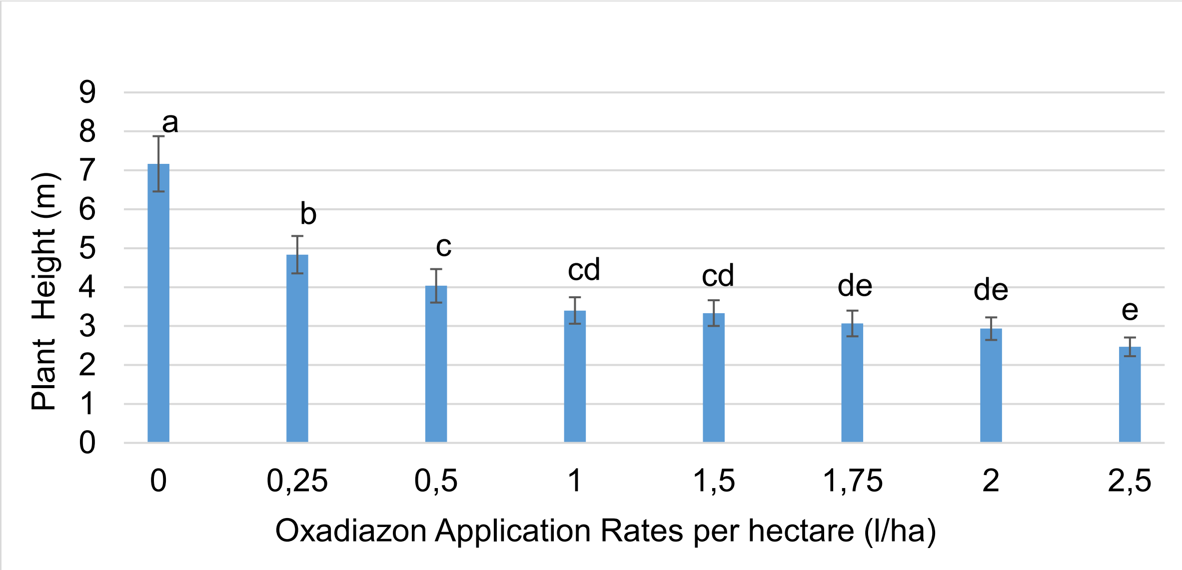

Figure 4.4.2: Plant height for Oxadiazon application rates on Broccoli seedlings.

Figure 4.4.2 illustrates the Plant height of seedlings averaged over the 7 treatments plus control. Plant height was measured 21 days after planting. The results for plant height of broccoli treatments were allocated into five groups, a, b, c, d, and e. According to figure 4.4.2 above (Tukey's Studentized Range (HSD) Test), it is satisfactory to signify that oxadiazon has effects on the plant height of broccoli seedlings. There were no significant differences amongst the oxadiazon rates 1.0 l/ha, and 1.5 l/ha, denoted with symbol “cd”, as there was also no significant difference amongst application rates 1.75l/ha and 2.0 l/ha, while other treatment rates were significantly different from each other as denoted with different symbols “b”, “c”, and “e” respectively. The treatments did show a significant difference in the plant height of broccoli seedlings when compared with the untreated, denoted with the symbol “a”.

4.4.3: Root Length Sensitivity Of Broccoli Hybrid Seedlings To Oxadiazon.

Table 4.4.3:ANOVA results for root length means of broccoli hybrid seedlings as affected by 7 application rates of soil applied Oxadiazon plus the untreated.

Source	DF	Sum of Squares	Root LengthMean	Mean Square	CV	F Value	Pr> F
Oxadiazon	7	117.09	7.74	16.73	3.86	187.59	<.0001

4.4.3.1: ANOVA: The obtained results illustrate that, there were significant differences in the root length by several application rates of Oxadiazon when compared to the untreated trial, and a plant height mean of 7.74m as shown above in Table 4.4.3

4.4.3.2:Oxadiazon Mean Separations For Root Length: Root length mean separation results for the 7 application rates of soil-applied Oxadiazon including the untreated. Figure 4.4.3 below depicts the results obtained from Oxadiazon Tukey's Studentized Range (HSD) Test for root length.

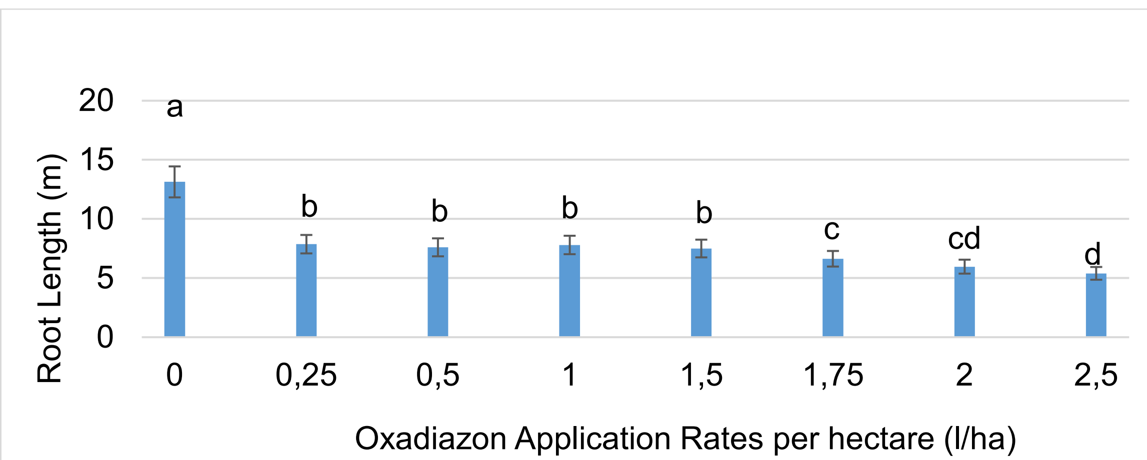

Figure 4.4.3: Root Length for Oxadiazon application rates on Broccoli seedlings.

Figure 4.4.3 illustrates the root length of seedlings averaged over the 7 treatments plus control. Root length was measured 21 days after planting. The results for the root length of broccoli treatments were allocated into four groups, a, b, c, and d. According to figure 4.4.3 above (Tukey's Studentized Range (HSD) Test), it is adequate to point out that oxadiazon has effects on the root length of broccoli seedlings. There were no significant differences amongst the oxadiazon rates 0.25l/ha,0.5l/ha,1.0l/ha, and 1.5l/ha, denoted with symbol “b”, while other treatment rates were significantly different from each other as denoted with different symbols “c”, “cd”, and “d” respectively. The treatments did show a significant difference in the root length of the broccoli seedlings when compared with the untreated, denoted with the symbol “a”.

4.4.4: Sensitivity Of Oxadiazon On The Leaf Injury Of Brocoli Hybrid Seedlings.

Table 4.4.4: ANOVA results for leaf injury means of broccoli hybrid seedlings as affected by 7 application rates of soil applied Oxadiazon plus the untreated.

Source	**DF**	**Sum of Squares**	**Leaf Injury Mean**	**Mean Square**	**CV**	**F Value**	**Pr> F**
Oxadiazon	7	13929.17	47.92	1989.88	11.27	68.22	<.0001

4.4.4.1: ANOVA: The obtained results illustrate that, there were significant differences in the leaf injury by several application rates of Oxadiazon when compared to the untreated trial, and a leaf injury mean of 47.92% as shown above in Table 4.4.4.

4.4.4.2: OxadiazonMean Separations For Leaf injury: Leaf injury mean separation results for the 7 application rates of soil-applied Oxadiazon including the untreated. Figure 4.4.4 below depicts the results obtained from Oxadiazon Tukey's Studentized Range (HSD) Test for leaf injury.

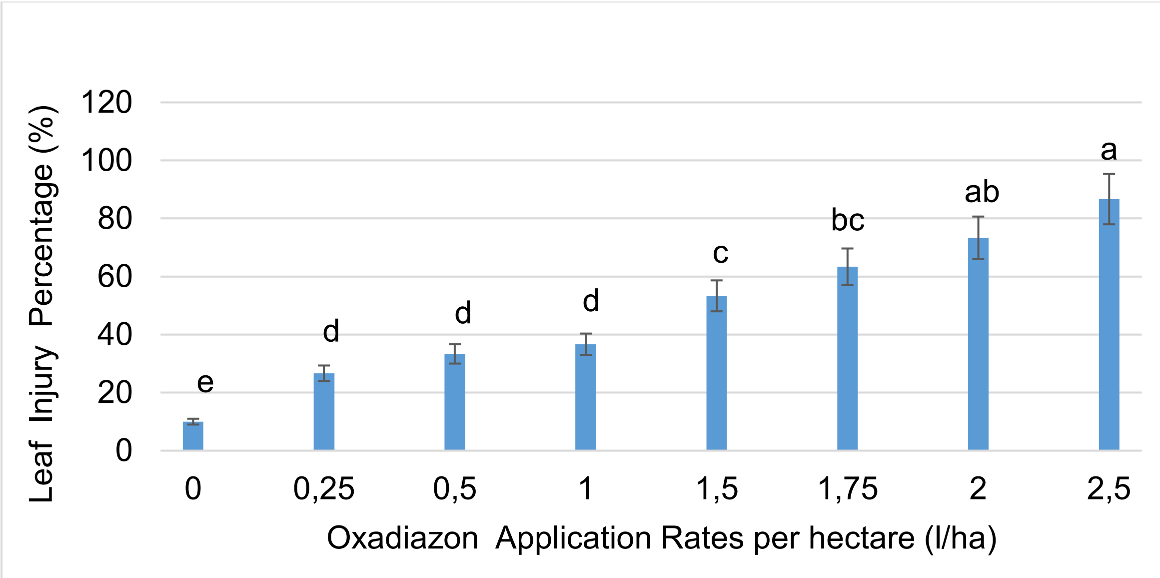

Figure 4.4.4: Leaf Injury for Oxadiazon application rates on Broccoli seedlings

.Figure 4.4.4 illustrates the leaf injury of seedlings that were calculated, averaged over the 7 treatments plus control. Leaf Injury data was taken 21 days after planting. The results for leaf injury of broccoli treatments were allocated into five groups, a, b, c, d, and e. From figure 4.4.4 above (Tukey's Studentized Range (HSD) Test) it is adequate to signify that the seven oxadiazon treatments have a significant effect on the visual leaf injury, also there were significant differences among the seven Oxadiazon rates. The leaf injury was seen to be proportionally related to the rates of application, the higher the oxadiazon rates the higher the leaf injury level, the leaf injury as seen with rates 0.25l/ha, 0.5l/ha, and 1.0l/ha as denoted with symbol “d” had lower leaf injury as compared to rates 1.5l/ha,1.75l/ha,2.0l/ha and 2.5l/ha denoted with “c”, “bc”, “ab” and “a” respectively which showed a higher level of leaf injury. The treatments of oxadiazon did have a significant difference in the leaf injury when compared with the untreated which is denoted with the symbol “e”.

4.4.5: Effect Of Oxadiazon On The Stunt Count Of Broccoli Hybrid Seedlings.

Table 4.4.5: ANOVA results for stunt count means of broccoli hybrid seedlings as affected by 7 application rates of soil-applied Oxadiazon plus the untreated.

Source	DF	Sum of Squares	Stunt Count Mean	Mean Square	CV	F Value	Pr> F
Oxadiazon	7	14116.67	49.17	2016.67	10.98	69.14	<.0001

4.4.5.1: ANOVA: The obtained results illustrate that, there were significant differences in the stunt count by several application rates of Oxadiazon when compared to the untreated trial, and a stunt count mean of 49.17% as shown above in Table 4.4.5

4.4.5.2: Oxadiazon Mean Separations For Stunt Count: Stunt count mean separation results for the 7 application rates of soil-applied Oxadiazon plus the untreated. Figure 4.4.5 below depicts the results obtained from Oxadiazon Tukey's Studentized Range (HSD) Test for stunt count.

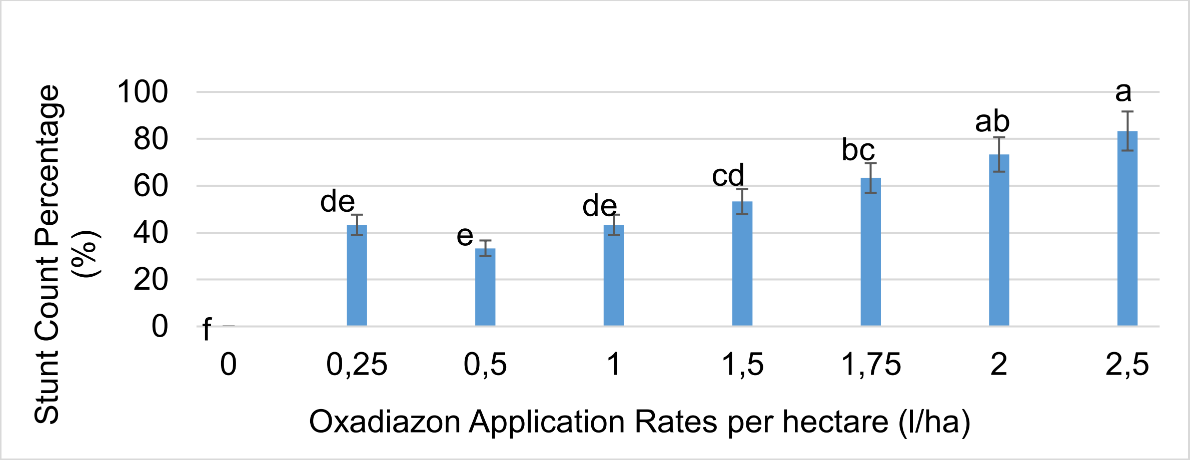

Figure 4.4.5: Stunt Count for Oxadiazon application rates on Broccoli seedlings.

Figure 4.4.5 illustrates the stunt count of seedlings that were recorded, averaged over the 7 treatments plus control. Stunt count data was taken 21 days after planting. The results for stunt count of broccoli treatments were allocated into six groups, a, b, c, d, e, and f. From figure 4.4.5 above (Tukey's Studentized Range (HSD) Test) it is adequate to signify that the seven oxadiazon treatments have a significant effect on the stunt count, also there were significant differences among the seven Oxadiazon rates. The stunt count was seen to be significantly different amongst the seven levels.

Application at rates 0.25l/ha and 1.0/ha as denoted with symbol "de" had no significant difference whilst other application rates (0.5l/ha, 1.5l/ha,1.75l/ha, 2.0l/ha, and 2.5l/ha) were significantly different. The treatments did show a significant difference in the stunt count percentage when compared with the untreated which is denoted with the symbol "f".

4.4.6: Necrosis percentage Sensitivity of Oxadiazonon Broccoli Hybrid Seedlings.

Table 4.4.6: ANOVA results for necrosis percentage means of broccoli hybrid seedlings as affected by 7 application rates of soil applied Oxadiazon plus the untreated.

Source	**DF**	**Sum of Squares**	**% Necrosis Mean**	**Mean Square**	**CV**	**F Value**	**Pr> F**
Oxadiazon	7	12462.50	65.42	1780.36	23.35	7.63	<.0.0004

4.4.6.1: ANOVA: The obtained results illustrate that, there were significant differences in the necrosis percentage by several application rates of Oxadiazon when compared to the untreated trial, and a necrosis percentage mean of 65.42% as shown above in Table 4.4.6

4.4.6.2: OxadiazonMean Separations For Necrosis percentage: Necrosis percentage Mean separation results for the 7 application rates of soil-applied Oxadiazon including the untreated. Figure 4.4.6 below depicts the results obtained from Oxadiazon Tukey's Studentized Range (HSD) Test for necrosis percentage.

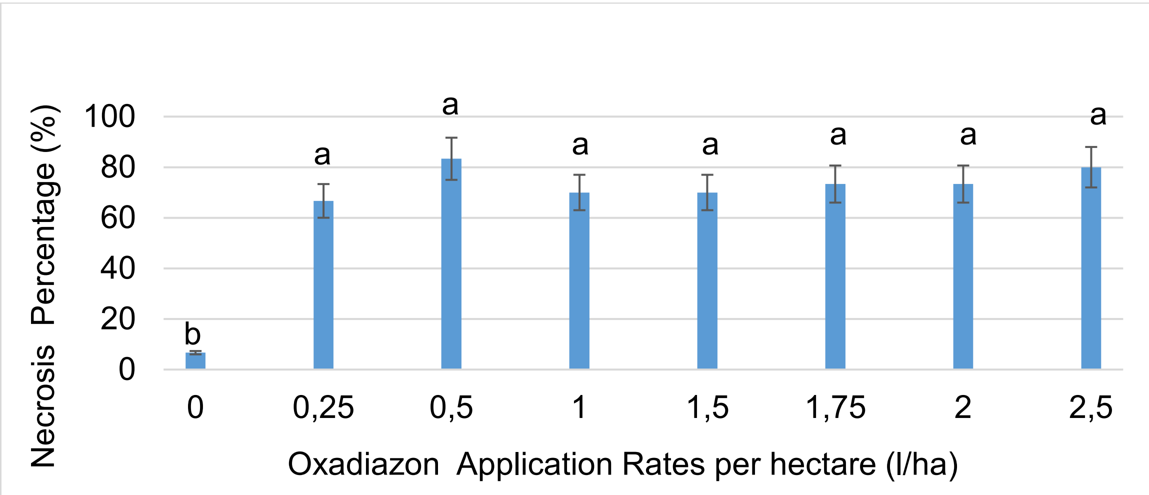

Figure 4.4.6: Necrosis Percentage for Oxadiazon application rates on Broccoli seedlings.

Figure 4.4.6 illustrates the percentage of seedlings that had necrosis, averaged over the 7 treatments plus control. Percentage necrosis was collected 21 days after planting. The results for the emergence of broccoli treatments were assigned into two groups which are from groups 1 to 2. According to figure 4.4.6 above (Tukey's Studentized Range (HSD) Test), it is sufficient to indicate that oxadiazon is sensitive in percentage necrosis of broccoli seedlings. There were no significant differences in the necrosis percentage amongst the seven oxadiazon treatment rates 0.25l/ha,0.5 l/ha,1.0l/ha,1.5 l/ha, 1.75 l/ha, 2.0 l/ha, and 2.5 l/ha which were assigned the symbol “a” but were all significantly different when compared with the untreated denoted with symbol “b”.

4.4.7: Days To Emergence Efficacy Of Oxadiazon On Broccoli Hybrids.

Table 4.4.7: ANOVA results for days to emergence means of broccoli hybrid seedlings as affected by 7 application rates of soil applied Oxadiazon plus the untreated.

Source	DF	Sum of Squares	Days toEmergence Mean	Mean Square	CV	F Value	Pr> F
Oxadaizon	7	2.96	4.38	0.42	9.33	2.54	<.0.0584

4.4.7.1: ANOVA: The obtained results illustratethat, there were no significant differences in days to Emergence by several application rates of Oxadiazon when compared to the untreated trial and days to emergence mean of 4.38days as shown above in Table 4.4.7

4.4.7.2: OxadiazonMean Separations for Days to emergence: Days to emergence Mean separation results for the 7 application rates of soil-applied Oxadiazon including the untreated. Figure 4.4.7 below depicts the results obtained from Oxadiazon Tukey's Studentized Range (HSD) Test for days to emergence.

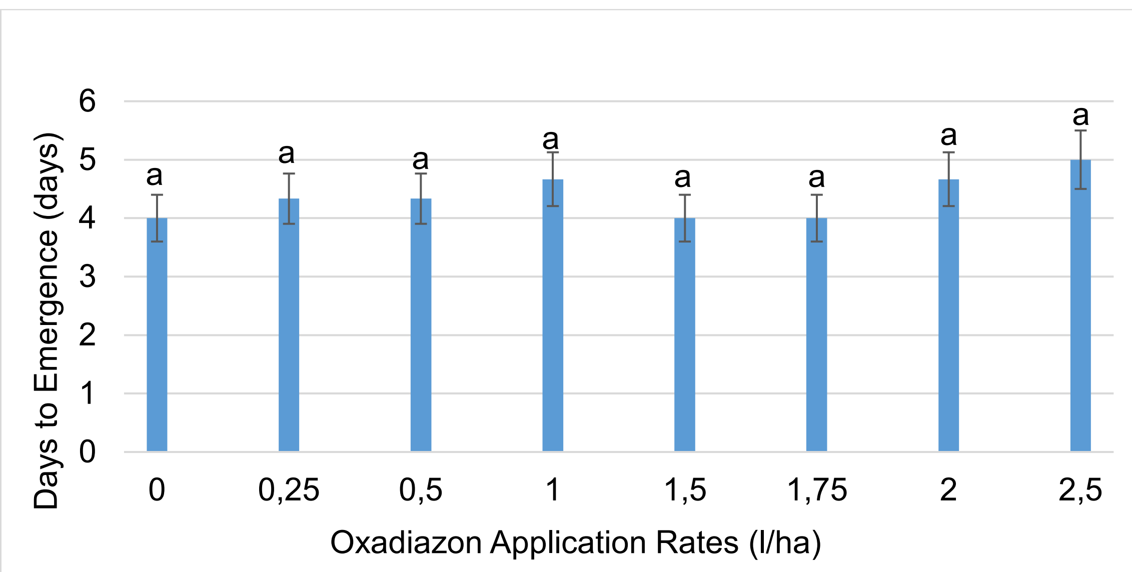

Figure 4.4.7: Oxadiazon application rates and Broccoli on Days to Emergence.

Figure 4.4.7 illustrates the days to the emergence of seedlings that emerged, averaged over the 7 treatments plus control. The emergence percentage was evaluated within 7 days after planting. The results for days to the emergence of broccoli treatments were allocated to one group alone a. According to figure 4.4.7 above (Tukey's Studentized Range (HSD) Test), it is evident to indicate that oxadiazon has no effects on days to the emergence of broccoli. There was no significant difference between the seven treatments and the control; they are all denoted with the symbol “a”. The different treatments have no level of significance on the days to emergence when compared with the untreated.

4.4.8: Germination Percentage Sensitivity To Oxadiazon Among Broccoli Seedlings.

Table 4.4.8: ANOVA results for germination percentage means of broccoli hybrid seedlings as affected by 7 application rates of soil applied Oxadiazon plus the untreated.

Source	DF	Sum of Squares	Germination Percentage Mean	Mean Square	CV	F Value	Pr> F
Oxadiazon	7	9895.83	67.08	1413.69	16.67	11.31	<.0001

4.4.8.1: ANOVA: The obtained results illustrates that, there were significant differences in the germination percentage by several application rates of Oxadiazon when compared to the untreated trial, and a germination percentage mean of 67.08% as shown above in Table 4.4.6

4.4.8.2: OxadiazonMean Separations For Germination Percentage: Germination percentage Mean separation results for the 7 application rates of soil-applied Oxadiazon plus the untreated. Figure 4.4.6 below depicts the results obtained from Oxadiazon Tukey's Studentized Range (HSD) Test for germination percentage**.**

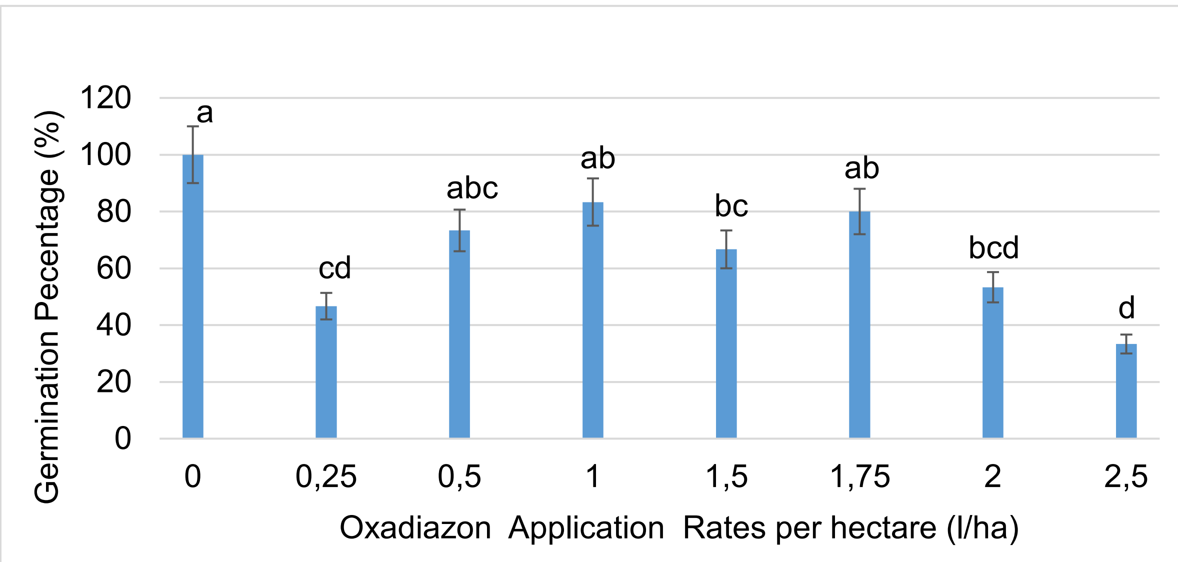

Figure 4.4.8: Oxadiazon application rates and Broccoli on germination percentage

Figure 4.4.8 illustrates the germination percentage of seedlings that were recorded, averaged over the 7 treatments plus control. Germination percentage was taken 7 days after planting. The results for germination percentage of broccoli treatments were allocated into four groups, a, b, c, and d. From the figure 4.4.8 above (Tukey's Studentized Range (HSD) Test) it is evident to indicate that the seven Oxadiazon treatments have a significant effect on germination percentage; also, there were significant differences among Oxadiazon rates. Germination percentage shows independence with the different rates of application, 1.0l/ha and 1.75ll/ha application rates denoted with “ab” show not to be significantly different, while other rates (0.25l/ha, 0.5 l/ha, 1.5l/ha, 2.0l/ha and 2.5l/ha) show independent germination percentages. The treatments had a significant difference in the germination percentage of the broccoli when compared with the untreated control which is denoted with the symbol “a”.

4.5: Estimated Gross Margin Expected With Using Of Halosulfuron Herbicide In Broccoli Under MagaliesburgSimulated Thermoperiods.

Gross profit margins and gross margins expected estimations per hectare using Halosulfuron herbicides were computed. The expected gross profit margins value would be the fundamental unit for investigating Halosulfuron usage feasibility. Table 4.5 below illustrates the gross margins, gross profit margin, and the average yields per hectare involved in broccoli crop production when Halosulfuron herbicide is used. The use of Halosulfuron on broccoli offers a Gross Margin Percentage of 83%, gross margins, and gross profit margins of R75, 996.01 per hectare.

Gross margin = (GI – TVC)

The Gross margin, The GI which means the Gross income, and the TVC which means Total variable Costs are all calculated in rands value.

When the gross profit margins and gross margins are being calculated, it is done with the mindset that the broccoli crop would be sold immediately from the farm and so there would be no need for including storage cost or loss in the calculations.

Maoba, (2016) described Gross margin as the value of net sales of produced goods, with the exclusion of the cost incurred in the production of the goods. Furthermore, Gross margin can be expressed in percentage using the principle below:

Gross Margin Percentage =	approximate Net Sales of *Broccoli* – approximate Input Costs of *Broccoli* x 100 approximate Net Sales of *Broccoli*

Table 4.5: EstimatedGross margin related with Halosulfuronherbicide

1. ASSUMPTIONS				
Spacing (cm) 100 x 30	Planting density	(pl/ha) 22,000		
Yield Range (kgs) 7,000 - 8,000	Average price (R/kg)	R11.50		
2. INCOME ($)	**Quantity**	**Unit**	**Unit Price**	**Total**
Sales	**8000**	**kg**	**11.50**	**R92000**
Total Income				**R92000**
3. DIRECT COSTS (R)	**Quantity**	**Unit**	**Unit Price**	**Total**
Land Preparation				
Harrowing	2	Ha	350	R700.00
Planting Material				
Seed (300g)	0.3	kg	4500	R1 350.00
Fertilizers				
NPK (13:13:21)	3	50kg bag	500	R1500
Herbicide				
Halosulfuron	0.7	1L	R138.74	R97.12
Fungicide				
Mancozeb	3	1kg	68.84	R206.52
Insecticide				
Chlorpyrifos	1.5	1L	63.50	R95.25
Steward	0.140	1L	1465	R205.1
Total variable Costs				**R4,153.99**
4.LABOUR INPUTS (person days)	**Unit**	**Quantity**	**Price R/Unit**	**Total R**
Planting	days	20	150	R3 000.00

Fertiliser Application	"	10	130	R1 300.00
Weeding	"	20	150	R3 000.00
Spraying	"	15	130	R1 950.00
Harvesting	"	20	130	R2 600.00
Total Labour Cost@R100/day		**85**		**R11,850.00**
Total Cost				**R16,003.99**
Gross Margin per Ha				**R75,996.01**
Gross Margin Percentage				**83%**

4.6: Estimated Gross Margin Expected With Using Metolachlor Herbicide In Broccoli Under Magaliesburg Simulated Thermoperiods.

Table 4.6 below illustrates the gross margins, gross profit margin, and the average yields per hectare involved in broccoli crop production when metolachlor herbicide is used. The use of Halosulfuron on broccoli offers a Gross Margin Percentage of 60%, gross margins, and gross profit margins of R24 159.43 per hectare.

Table 4.6: Estimated Gross margin related with Metolachlor herbicide

1. ASSUMPTIONS				
Spacing (cm) 100 x 30	Planting density	(pl/ha) 22,000		
Yield Range (kgs) 7,000 - 8,000	Averageprice (R/kg)	R11.50		
2. INCOME ($)	**Quantity**	**Unit**	**Unit Price**	**Total**
Sales	**3,500**	**kg**	**11.50**	**R40 250.00**
Total Income				**R40 250.00**
3. DIRECT COSTS (R)	**Quantity**	**Unit**	**Unit Price**	**Total**
Land Preparation				
Harrowing	2	Ha	350	R700.00
Planting Material				
Seed (300g)	0.3	kg	4500	R1350.00
Fertilizers				
NPK(13:13:21)	3	50kg bag	500	R1500.00
Herbicide				
Metolachlor	1	1L	R183.70	R183.70
Fungicide: Mancozeb	3	1kg	68.84	R206.52
Insecticide				
Chlorpyrifos	1.5	1L	63.50	R 95.25
Steward	0.140	1L	1465	R 205.1
Total variable Costs				**R4240.57**
4.LABOUR INPUTS (person days)	**Unit**	**Quantity**	**Price R/Unit**	**Total R**

Planting	days	20	150	R3000.00
Fertiliser Application	“	10	130	R1300.00
Weeding	“	20	150	R3000.00
Spraying	“	15	130	R1950.00
Harvesting	“	20	130	R 2600.00
Total Labour Cost@R100/day		**85**		**R11,850.00**
Total Cost				**16090.57**
Gross Margin per Ha				**R24 159.43**
Gross Margin Percentage				**60%**

4.7: Estimated Gross Margin Expected With Using Clomazone Herbicide In Broccoli Under Magaliesburg Simulated Thermoperiods.

Table 4.7 below illustrates the gross margins, gross profit margin, and the average yields per hectare involved in broccoli crop production when clomazone herbicide is used. The use of Halosulfuron on broccoli offers a Gross Margin Percentage 53% gross margins and gross profit margins of R18 434.49 per hectare.

Table 4.7: Estimated Gross margin related with Clomazone herbicide.

1. ASSUMPTIONS				
Spacing (cm) 100 x 30	Planting density	(pl/ha) 22,000		
Yield Range (kgs) 7,000 - 8,000	Average price (R/kg)	R11.50		
2. INCOME ($)	**Quantity**	**Unit**	**Unit Price**	**Total**
Sales	**3000**	**kg**	**11.50**	**R34 500.00**
Total Income				**R34 500.00**
3. DIRECT COSTS (R)	**Quantity**	**Unit**	**Unit Price**	**Total**
Land Preparation				
Harrowing	2	Ha	350	R700.00
Planting Material				
Seed (300g)	0.3	kg	4500	R1350.00
Fertilizers				
NPK(13:13:21)	3	50kg bag	500	R1500.00
Herbicide				
Clomazone	1	1L	R158.64	R158.64
Fungicide				
Mancozeb	3	1kg	68.84	R206.52
Insecticide				
Chlorpyrifos	1.5	1L	63.50	R95.25
Steward	0.140	1L	1465	R205.1
Total variable Costs				**R4215.51**
4. LABOUR INPUTS (person days)	**Unit**	**Quantity**	**Price R/Unit**	**Total R**
Planting	days	20	150	R3 000.00

Fertiliser Application	“	10	130	R1 300.00
Weeding	“	20	150	R3 000.00
Spraying	“	15	130	R1 950.00
Harvesting	“	20	130	R2 600.00
Total Labour Cost@R100/day		**85**		**R11, 850.00**
Total Cost				**R16065.51**
Gross Margin per Ha				**R18434.49**
Gross Margin Percentage				**53%**

4.8: Estimated Gross Margin Expected With Using Oxadiazon Herbicide In Broccoli Production UnderMageliesburgSimulated Thermoperiods.

Oxadiazon herbicide applied pre-plant incorporated in broccoli caused an undesirable leaf injury to broccoli from week two after crop emergence and the injury persisted till the third week and led to a high level of death. The value in using oxadiazon herbicide produced negative gross margins and gross profit margins revealing its failure. The low quality and reduced amount of yield in using oxadiazon herbicide in broccoli production were credited for the attributed to negative issues such as high leaf chlorosis, stunting, visual leaf injury, and death of the broccoli crop. A key attribute of oxadiazon is that it is barely favorable for weed control in a few crops (primarily soybeans and rice). There is a wide range in the natural resistance of crops and weeds to these compounds (Sherman et al., 1991; Matsumoto et al., 1994); however, there is no evidence that many weeds have become resistant to these herbicides as the result of selection pressure. There are several mechanisms of resistance, including the reduced sensitivity of Protox, resistance to singlet oxygen, and metabolic rapid degradation of the herbicide. From the experiment conducted, the crop injury was very persistent to the extent that in less than three weeks the necrotic condition of the crop was more than 65% and the visual injury was at about 48% also because about 72% emerged and only 67% germinated of which the ratio of survival in the population was very low and at about the third week the death of the crop was at 100% for all the treated plants with exception of the untreated.

CHAPTER 5

5.0: DISCUSSION.

5.1: Influence Of Broccoli Hybrid To Metolachlor Applied Soil Under Simulated Thermoperiods And Humidity Of Magaliesburg.

Climatic and environmental conditions that are favorable in the tolerance of cole crops species to Metolachlor are easily demonstrated in the greenhouse, as it is also quicker and economically viable (Anonymous, 2017). The application rates of the herbicide applied were chosen from those of past authors with regards to the labels for other similar crops. The mode of action of Metolachlor is shoots and seedling growth inhibition (Crop Watch, 2016). The trial utilized growth data and visual rating to examine the relationship display that exists between necrotic and visual injury effects and reduction in the growth of broccoli hybrid when using Metolachlor soil-applied herbicides.

A pre-emergence application of Metolachlor herbicide on cabbage, tomatoes, and cucumber was conducted, the results showed that Metolachlor had an inconsistent tolerance on these crops (Gorski, 2008). It was discovered that the tomato and cucumber germination rate lowered with an increasing Metolachlor dosage. Lettuce crop germination at 0.56 kg/ha and above was totally subdued. Gorski (2008), showed that with increased dosage, the seedlings' chlorotic condition and stunted growth became higher as was described in the Metolachlor mode of action. According to (Sikkema et al., 2007) from a trial demonstrated on the pre-transplant incorporated application of Metolachlor on cabbage at 0.8l/ha, 1.6l/ha, and 2.4l/ha application rates, there was no visual injury, marketable head number, marketable head weight and yield of cabbage at any of the Metolachlor application rates or application timings evaluated. Sikkema et al., (2007) suggested that metolachlor at the doses evaluated has the potential for use in cabbage in Ontario. Metolachlor pre-emergence soil-applied at 0.5l/ha on broccoli was observed to be safe (Fennimore, 2006), it efficiently eliminated summer/spring weeds better than Dacthal standard. Metalochlor applied trial on cabbage was tolerated before transplanting (Al-Khatib et al., 1995).

Even though broccoli sensitivity to different many herbicides was established, advanced research into duration and herbicides' effect in a variety of weeds control is necessary. Using pot trials do expose limitations in simulated conditions supporting damages caused by herbicide because if no damage is experienced using pots there is a thin chance of damages being caused on the field environment. on the critical parameters measured, it is only a little safe for the Metolachlor herbicide to be applied at the rate ranging from 0.4l/ha – 1.2l/ha of Metolachlor as the negative effects were at average at 1.2l/ha, for direct-seeded broccoli in black clay soils that are generated from Magaliesburg, South Africa. Hopen, (1993) and Harrison, (1998) presented that although the broccoli hybrid exhibited intolerance Metolachlor dosage, it is important to note that the Metolachlor effect does differ amongst brassica hybrids.

5.2: CropTolerance Efficacy Of Clomazone Applied Soil To Broccoli Hybrid Under Simulated Mageliesburg Humidity And Thermoperiods.

Hopen et al., (1993), reported the determination of Clomazone tolerance is very essential in the growth of broccoli. Seedling and root growth inhibition is the mode of action of Clomazone; also injury develops within a week of exposure (Crop Watch, 2016). A short thick underground shoot may be observed when the crop is in direct contact with herbicide and stunting becomes obvious.

Harrison &Farnham, (2013) in a similar greenhouse experiment comparing the tolerance of clomazone in broccoli and cabbage using visual rating and growth data, it was reported that at 1 ppm l/ha the visual injury ratings were similar. Also, the shoot weight reductions were less than 50% when compared with the control. The broccoli shoot weight reduction was over 50% at 1ppm/l/ha application rates. The visual injury ratings for the cultivars used were quite like that of the early growth reduction. The experiments were also repeated on the field and it was reported that the results were similar in both the field and the greenhouse, though the greenhouse method was mostly preferred because it is less costly and more rapid nature in analysis to examine cultivars and germplasm lines for tolerance to clomazone.

In a trial conducted by Scott et al., (1995) evaluation for pre-planting incorporated Clomazone application for weed management in several cole crops including broccoli, cauliflower, green cabbage, pakchoi, and red cabbage, it was reported that pakchoi was the most sensitive to Clomazone, however, the cultivar of green cabbage and cauliflower used did show a similar tolerance when compared to those used by (Hopen et al., 1993). Scott et al., (1995), however, concluded that pre-plant-incorporated application of clomazone could be said not secure for use in cole crops because of the risk of crop injury of which they based their observation on the label precaution which reads cole crops roots transplanted should be below the herbicide zone to reduce injury and mechanical incorporation is not permitted (FMC Corp., 2005).

Using very high rates in the field is undesirable because of the potential for clomazone to persist in the soil and injure subsequent crops (FMC Corp., 2005). They also reported that most cultivars showed minor early chlorosis caused by Clomazone at 2 WAT, which was often not observed at 6 WAT. Not so much research on Clomazone in cole crops has been in print. Broccoli plants with growth reduction as a result of Clomazone injury may be able to produce full-sized heads more readily than can be produced by Clomazone injured cabbage plants. Harrison and Farnham (2011), concluded that their result indicates that Clomazone tolerance in broccoli may be enough to allow safe use of the herbicide at the recommended rate for cabbage, 0.25 lb/acre for coarse soils. Further research is needed to evaluate broccoli response in different soils and environments before Clomazone can be recommended for broccoli. This trial is justified because Clomazone provides persistent control of some annual grasses and some broadleaf weeds and it controls several important broadleaf weeds that are not controlled by the other preemergence herbicides registered for broccoli weed management.

5.3: Effect Of Halosulfuron On Shoot And Root Plant Growth Parameters Of Broccoli Hybrid Under Simulated Magaliesburg Humidity AndThermoperiods.

According to Umeada, (2001), Halosulfuron herbicide is being developed for weed control in cucurbit crops, though it has demonstrated exceptional activity on purple nutsedge (*Cyperus rotundus*) when applied postemergence. A trial was conducted to evaluate and determine the safety of Halosulfuron on typical cole crops like lettuce, broccoli, and spinach. The test was arranged in a randomized complete block design with four replicates and this was the authority on which this application rate was conducted though it was done in three replicates. Halosulfuron is a seedling growth and root growth inhibitor herbicide (Crop Watch, 2016). It is fastly absorbed by roots and foliage and it is translocated throughout the plant causing rapid growth inhibition in susceptible plants. The root length results as seen in figure 4.2.3 indicated that the broccoli hybrid was tolerant to Halosulfuron at rates 0.055 and 0.070l/ha. Halosulfuron has a moderately shorter soil residual capacity that could allow planting back typical desert-grown vegetable crops safely in an intensive rotational system (Umeada,2011). In the findings of (Umeada 2011), it was reported that Halosulfuron did not affect the plant stand number of broccoli, lettuce, and spinach. The number of plants of each crop that was counted was like the untreated check, the crop height also was not affected; in fact, most of the crop heights were similar or exceeded the average plant height of the untreated checks. Broccoli and lettuce fresh weights did not exhibit differences between treatments and the untreated check. There were no differences in the fresh weights obtained when Halosulfuron was applied at PRE and POST application. The plant height of the broccoli from Figure 4.2.2 showed that broccoli was tolerant at 0.055 and 0.070l/ha. It was recorded that cole crops planted successively for three seasons after an initial Halosulfuron application were not appreciably injured. Figure 4.2.4 indicated that broccoli leaf injury was tolerated at rates 0.015, 0.070, and 0.085l/ha. However, a sequential PREE plus POST treatment or POST treatment alone did not cause greater injury even when more Halosulfuron was applied (Umeada, 2011).

Soltani et al., (2014a, b), reported from a trial conducted that Halosulfuron applied pre-plant incorporated had no injury in the white bean. Although, Halosulfuron applied Post-emergence did cause 9, 4, and 1% injury in white bean at 1, 2, and 4 weeks after application (WAA), respectively (Soltani 2012a, b). It was further emphasized that the trial indicated that it is safer to apply Halosulfuron PPI or PRE rather than POST in white bean (Soltani 2012a, b). In a different trial where Halosulfuron was applied to a cantaloupe crop, it was reported that the cantaloupe fruit size was not affected by the Halosulfuron treatments and this agreed with previous Halosufuron research on cantaloupe (Johnson &Mullinix 2002, 2005).

Umeada&Beeter (2002), carried out research to determine the effect of Halosulfuron applied PREE on broccoli and red table beets. It was reported that the broccoli that emerged and established a stand did not show any significant differences or numerical trends between the untreated check and the different Halosulfuron treatment rates. The author in his results obtained also as shown in Table 4.2.1 and Table 4.2.8 that there was no significant difference in the emergence and germination percentage for all the different treatments levels and the untreated check with an average of 95.41% and 94.17% respectively. Umeada&Beeter (2002), also reported that none of the broccoli treated by Halosulfuron showed any crop injury after approximately one month when the stand was established and the crop vigor was excellent and progressing normally. This also was seen from the results obtained by the author in tables 4.2.4and table 4.2.5 which are the results of the visual injury and stunt count where the visual injury was 10.41% (<11%) and the stunt count was 11.67% (<12%) respectively. Likewise, the necrotic conditions from table 4.2.6 of the plants were at 10.83% (<11%). This figure was the lowest when compared to the other three herbicides the author was evaluating which are Metolachlor, Clomazone, and Oxadiazon.

From the results obtained it is evident that the safe application rates for Halosulfuron application rates are 0.055 and 0.070l/ha which is the average point at which an increase of the Halosulfuron either increases or decreases the effect on the critical parameters measured.

Umeada, (2011), reported alfalfa plant heights were slightly reduced when compared to the untreated trial except where the highest rate applied POST was less affected than the lower rate without an explanation, the spinach also planted where POST applications were made were more likely to show a slight reduction in fresh weight compared to the untreated trial and where PRE treatments were applied. Halosulfuron does not seem to be a major restraint to typical crop rotational schemes in the diverse desert agricultural systems. The soil textural differences, tillage practices, number of applications, and the rates of application may be a consideration for further research to evaluate the absolute safety of Halosulfuron in the desert. The South Africa Pest Management Regulatory Agency requires an herbicide causing a maximum of 10% crop injury for it to be registered as a new herbicide, even though farmers and growers often demand 5% or less visible crop injury to maintain using a herbicide in their weed control program. The results obtained by the author in the visual injury, necrosis, and stunt count did exceed by about 1-2% the required level for a new herbicide to be registered in South Africa, therefore, the author also suggests that further research could be done to achieve less than 10% so that Halosulfuron can be registered for broccoli in the weed management program.

5.4: Tolerance Of Broccoli Hybrids To OxadiazonUnder SimulatedMagaliesburgThermoperiods And Humidity.

Oxadiazon mode of action is that which inhibits protoporphyrinogen oxidase PPO leading to irreversible cell membrane damage. Oxadiazon is applied as foliar sprays which cause very rapid cellular collapse and desiccation. The most effective of these compounds can be used at rates of only a few grams per hectare. Oxadiazon is an oxidase protoporphyrinogen inhibitor (PROTOX), which operates in the accumulation of protoporphyrinogen within the chloroplast, diffusing into the cytosol, the oxidation occurring at protoporphyrin IX (precursors of chlorophyll), which is a photodynamic pigment. The oxadiazon applied in the cotyledons of *Cucumis sativus* promoted the disruption of cell membranes after one hour of exposure to light (Duke et al., 1989), rapidly dehydrating and disintegrating the organelles cells.

According to a trial conducted by Mendes et al., (2012), it was reported that Oxadiazon rate of sorption is related to the organic component content of the soils (Comoretto et al., 2008). Also, the sorption of the herbicide in the suspended sediments can reduce the rates of degradation of Oxadiazon within the soil (Lin et al., 2000; Ying & Williams, 2000), producing carboxylic acid, phenolic derivatives and polar dealkylated products, which were identified as the metabolites of degradation of Oxadiazon in the soil (Ying & Williams, 1999). In addition, the authors stated that the sorption of Oxadiazon has no relationship with the clay content of the soil, but with the organic component content only. The highest values of this coefficient are indicative of better retention of the herbicide by the soil and, consequently, less leaching (Oliveira et al., 2004). Important information to note is that the organic component content of the soil is determined by the balance of the inputs, such as the incorporation of plant residues and the application of organic compounds, and then exits through the oxidation and decomposition of the Organic matter of the soil (Leite et al., 2003).

The untreated trial did enhance the stunt count, necrotic percentage, root length, plant height, and days to the emergence of broccoli when treated with Oxadiazon at the application rates of the author.

Lifshitz& Safer (1974), studied the effect of Oxadiazon post-emergence treatments on weeds and onions at different stages of growth with onion cv. Besor in sandy loam soil. They showed that at the flag leaf stage, 20 days after sowing, Oxadiazon at 0.375 kg per ha caused some initial injury but there was only a 20 percent reduction in bulb yield. Oxadiazon at 0.75 kg per ha caused a severe reduction in the stand and a 52 percent reduction in yield. At the first leaf stage, 31 days after sowing no significant stand reduction was caused by Oxadiazon at the above rates and yields were 6 to 11 percent lower than the weeded control. Oxadiazon was not sufficiently effective against *Diplotxis* sp, *Sinapsis* sp, *Phalaris* sp, and *Lolium* sp; however, some control was obtained, especially the earliest treatment given all the 3 leaf stages reached 96 days after sowing, the importance of early post-emergence weed control was stressed. The results obtained by the author were not close to the requirement needed for a herbicide to be registered, hence a further investigation would be suggested to ascertain at what rates and timing it is best to apply Oxadiazon to broccoli production.

5.5: Estimated Gross Margins Associated With Use Of Metolachlor, Halosulfuron, ClomazoneAnd Oxadiazonin Broccoli Under Simulated MagaliesburgThermoperiods And Humidity.

The author based a presumption on the gross profit and gross margins per hectare of broccoli related to the use of soil-applied herbicides, Clomazone, Metolachlor, Oxadiazon, and Halosulfuron. When the gross profit margins and gross margins are being calculated, it is done with the mindset that the broccoli crop would be sold immediately from the farm and so there would be no need for including storage cost or loss in the calculations. Maoba, (2016) described Gross margin as the value of net sales of produced goods, with the exclusion of the cost incurred in the production of the goods. Furthermore, Gross margin can be expressed in percentage using the principle below: Table 4.5 illustrates the gross margins, gross profit margin, and the average yields per hectare involved in broccoli crop production when Halosulfuron herbicide is used. The use of Halosulfuron on broccoli offers a Gross Margin Percentage of 83%, gross margins, and gross profit margins of R75, 996.01 per hectare. Table 4.6 illustrates the gross margins, gross profit margin, and the average yields per hectare involved in broccoli crop production when Metolachlor herbicide is used. The use of Halosulfuron on broccoli offers a Gross Margin Percentage of 60%, gross margins, and gross profit margins of R24 159.43 per hectare. Table 4.7 below illustrates the gross margins, gross profit margin, and the average yields per hectare involved in broccoli crop production when Clomazone herbicide is used. The use of Halosulfuron on broccoli offers a Gross Margin Percentage 53% gross margins and gross profit margins of R18 434.49 per hectare.

However, Oxadiazon led to a high degree of broccoli death, therefore, the herbicide gross margin was not calculated. In relation to this study, the use of Halosulfuron in broccoli hybrid production under Magaliesburgthermoperiods produced more viable results when compared to the use of Metolachlor, Clomazone, and Oxadiazon herbicides.

CHAPTER 6

6.0: CONCLUSION AND RECOMMENDATIONS.

The results obtained in this trial show that the different responses of Clomazone, Oxadiazon, Metolachlor, and Halosulfuron soil-applied herbicides are dependent on the application rates. The soil-applied Pre-plant incorporated applications of Halosulfuron showed a minimum (less than 11%) and visual injury on broccoli. The pre-planting incorporated application of Metolachlor and Clomazone to direct-seeded broccoli created a significant injury to broccoli hybrids at the proposed dosage. The situation was poor for Oxadiazon application because it produced a continuous crop injury which led to the deaths of so many plants. The recorded stunting reduced plant heights, reduced root numbers and visual leaf injury were quite high for the metolachlor and clomazone applied herbicides as also the crop injury did increase with the increased application rates. The study did help establish that emergence percentage, germination percentage, plant height, and root length, are nice features in evaluating the effects of these four herbicides on broccoli seedlings, these factors were seen to have decreased with an increased herbicide application rate. Likewise, the stunt count and necrosis percentage were good observable characteristics in the four herbicides activities on broccoli seedlings, these characteristics were seen to have increased with an increasing herbicide application rate. Broccoli crop hybrids need to be examined for sensitivity before using Halosulfuron, Metolachlor, Clomazone, and Oxadiazon to prevent yield losses which may occur when a vulnerable hybrid is used. From the obtained results, Halosulfuron was seen to be safe when applied at rates 0.015l, 0.025l 0.04l, 0.055l, and 0.07l/ha PREE in broccoli. The results of this trial signify that Halosulfuron herbicide has the potential for use in broccoli. Further research is suggested to determine the accurate stages, timings, and rates for applying soil-applied Halosulfuron herbicide to broccoli crop propagation.

Furthermore, on the potentiality of sulfonylurea family to be recommended for broccoli is according to the findings of (Umeada, 1999) it was reported that applying thifensulfuron at 0.003 and 0.004l/ha did not cause any broccoli to stand reduction. It was also stated that none of the treatments used caused any obvious crop stunting as the crop approached maturity, no weeds were present during the broccoli crop establishment period, therefore, no weed control efficacy was evaluated, although it was suggested that the herbicide should be tested again to evaluate weed control efficacy at the selected rates since crop tolerance was confirmed.

Metolachlor applied pre-plant incorporated also did show some level of potentiality in the control of weed in broccoli production as it showed good level in the germination and emergence but it did finally sub come to necrotic conditions and visual injury which did affect the growth and development and subsequently led to the reduction in the number of plants stand as it approached 21 days after planting.

Clomazone applied at pre-plant incorporated showed that there were early visual injury and early growth reduction in the broccoli as can be also seen in the germination and emergence percentage obtained in this trial as this concurs with the statements of Scott et al., (1995) when they concluded that pre-plant-incorporated application of clomazone may not be safe for use in cole crops because of the risk of crop injury. Clomazone applied at pre-plant incorporated as conducted by Harrison & Farnham (2000) in a greenhouse experiment discovered that the similarity between visual clomazone injury and early growth reduction in broccoli and cabbage, and cultivar differences in Clomazone tolerance were detected using visual rating and growth data. The cultivar differences in Clomazone tolerance observed in this system correspond to those observed in our field experiment and those reported by (Hopen et al., 1993). Scott et al.,(1995) concluded that pre-plant-incorporated application of Clomazone may not be safe for use in cole crops because of the risk of crop injury, and their observation probably contributed to the label precaution that roots of transplanted cabbage should be below the herbicide-treated zone to reduce injury, and mechanical incorporation is not recommended (FMC Corp., 2005). The author obtained results that were quite high from the Clomazone application rates, it is suggested that different timings, rates, hybrid, and soil types could be further investigated to determine the sensitivity of broccoli to soil-applied pre-plant Clomazone herbicide.

Oxadiazon did show that it is susceptible to broccoli crop when applied pre-plant incorporated at the application rates used by the author on Magaliesburg soil, this has also indicated that broccoli is not tolerant to Oxadiazon applied pre-plant incorporated on Magaliesburg soil, so it is suggested that different timings, rates, and soil could be further tested to discover its efficacy on broccoli hybrid seedlings.

Even though broccoli tolerance to Halosulfuron was established, further research into the variety of weed control and duration of efficient control and elimination that can be expected from Halosulfuron is needed. Future research needs to also consider trying on the field because the soil space volume for the root growth is small in the pot. The capability to compare results obtained from the greenhouse with that from field conditions is a significant limitation of the demonstration. A suggestion that the broccoli hybrid sensitivity trial is trialed in the field as well to determine whether seedling sensitivity to the herbicides affects the yield reductions at maturity. This would help in the decisions taken in registering the herbicide for use in broccoli weed management.

Although Halosulfuron, Clomazone, Metolachlor, and Oxadiazon herbicides are not registered for broccoli weed management in South Africa under the Act no 36 of 1947(Agricultural Remedies Act) the scholar is suggesting that hence these herbicides never affected germination and emergence, there may be possibilities of further research to establish their usefulness in weed control in the future and determine what accurate stage of the crop growth to apply any of these herbicides.

REFERENCES

Adeyemo, R., Oke, J.T.O.,&Akinola, A.A., 2010. *Economic efficiency of small-scale farmers in Ogun State, Nigeria*. Tropicultura; *28*(2):84-88.

AkeyDekker, J., 1990. *Competition for Light between Velvetleaf and Soybean.*Weed Res. 30: 400–412.

Al-Khatib, K., Kadir, S.,& Libbey, C., 1995. *Broadleaf weed control with clomazone in pickling cucumber* (*Cucumissativus*). Weed Technol. 9:166–172.

Allemann, J., 1993. *Some Factors Affecting Alachlor Selectivity in Sunflower* (*Helianthus Annuus L*). M.Sc. (Agric.) Dissertation, University of Pretoria, Pretoria.

Amrhein, J.,&Gerber, H. R., 1985. CGA 131'036: *A new herbicide for broadleaved weeds control in cereals.* In 1985 British Crop Protection Conference, Weeds, Vol 1. BC Publications, Surrey, pp55-62. Available Online: http://www.cwss.org/proceedingsfiles/2002/34_2002.pdf. Accessed: 02/12/2013.

Anderson, R. J., Norris, A. E., & Hess, F. D., 1994. *Synthetic chemicals that act through the porphyrin pathway*: Am. Chem.SOC.W Washington, D.C.A survey. ACS Symp. Ser. 559, 18-33.

Andreoli, C., Andrade, V.R., Zamora, S.A.,& Gordon, M., 2002. *Influence of seed germination and sowing density on stand establishment and corn yield*. Brazilian Journal of Seeds 24: 1-5.

Baer, U., 1999. *Fate of Soil Applied Herbicides: Experimental Data and Prediction of Dissipation Kinetics*. Journal. *Environ. Qual.* 28(6): 1760-1780.

Bailey, W.A., Wilson, H.P.,& Hines, T.E., 2002.*Response of potato (Solanumtuberosum) and selected weeds to sulfentrazone*. Weed Technol 16:651–658.

Beard, R., 2001. *Effect of Water pH on the Chemical Stability of Pesticides*. Utah State University Fact Sheet. AG/Pesticides/14.

Bell, C.E., 1995. *Broccoli (Brassica oleracea var botrytis) yield loss from Italian ryegrass (Loliumperenne) interference.* Weed Sci. 43: 117-120.

Bell, C.E., 2000. *Weed control in carrots: The efficacy and economic value of linuron*. Hortscience 35: 1089-1091.

Bell, C.E., Fennimore, S.A., McGiffen, M.E. Jr., Lanini, W.T., Monks, D.W., Masiunas, J.B., Bonnanno, A.R., Zandstra, B.H., Umeda, K., Stall, W.M., Bellinder, R.R., William, R.D., &McReynolds, R.B., 2000. MyviewWeed Sci.48:1.

Belles, D., & Nissen, S., 2006. *Soil Dissipation and Biological Activity of Metolachlor and S-Metolachlor in Five Soils*. Pest Management. Science. 610-627.

Bhayan, B.S., Khurana, S.C., Dhankar, B.S., &Pandita. M.L., 1985. *Weed control studies in cauliflower vaL Hisar-1.* Haryana Journal of Horticultural Science 14:85-89.

Bhowmik, P.C.,&McGlew, E.N., 1986. *Effect of oxyfluorfen as apretransplant treatment on weed control and cabbage yield*. J.Am.Soc. Hort. Sci. 111: 686–689.

Bhutani, R.D., Pandita, M.L., & Singh, B., 1978. *Weed control studies in cauliflower variety Snowball- 16*. Haryana Journal of Horticultural Science 7: 187-191.

Boswell, V.R., 1949. *Our vegetable travellers*. Natl.Geogr.Mag. 96:145-217.

Boutsalis, P., 2001. *Herbicide Resistance Action Committee (HRAC)*. Available Online: http://www.hracglobal.com/. Accessed: December 2, 2013.

Brown, H. M., 1990. *Mode of action, crop selectivity, and soil relations of the sulfonylurea herbicides*. Pestic. Sci. 29:263-281.

Brown, D., &Masiunas, J., 2002. *Evaluation of herbicides for pumpkin (Cucurbita spp.).* Weed Technol. 16: 282–292. doi:10.1614/0890-037X (2002)016 [0282: EOHFPC] 2.0.CO;2.

Brucher, J*.,* 1997. *Temperature Dependence of Linuron Sorption to Different Agricultural Soils.* J. Environ. Qual. 26: 1320–1340.

Bruins, D*.,* 2007. *Differential Vegetable Crop Responses to Mesotrione Soil Residues a Year after Application.* Crop Protection, 26(9): 1390-1405.

Buser, H., Muller, M.D., &Poiger, T., 2001. *Isolation and Identification of the Metolachlor Stereoisomers Using High Performance Liquid Chromatography.*Journal of Agricultural Food and Chemistry. 49 (1): 38-60.

Burpee,2016.Accessedonlineathttp://www.burpee.com/ gardenadvicecenter/ vegetables/cauliflower/all-about-cauliflower/article10220.htmlon 12/10/2018**.**

Byrne, D.N., &Baciewicz, P., 2000. Vegetable Report, University of Arizona, College and Agriculture and Life Sciences, AZ 1177, August 2000.

California Weed Conference, 1985. *Principles of Weed Control in California*. Thomson Publications. Fresno, California.

Camargo, E. R. et al., 2012. *Interaction between saflufenacil and imazethapyr in red rice (Oryza ssp.) and hemp sesbania (Sesbaniaexaltata) as affected by light intensity*. Pest Manag. Sci., v. 68, n. 7, p. 1010-1018.

Carolyn, J., 2007. *Weed Control Guide for vegetable crops*. Pesticide safety education program, Michigan State University, East Lansing.

Carpenter, A. C., Senseman, S. A., & Cralle, H. T., 1999. *Adsorption– desorption of halosulfuron on selected Texas soils*. Proc. South. Weed Sci. Soc. 52:211.

Carter, A. H., 2007.*The Effect of Imazamox Application Timing in the Pacific Northwest.* Weed Technology, 21(4): 890-905.

Carter, A. H., Hansen, J., Koehler, T., Thill, D. C.,&Zemetra, R. S., 2007. *The effect of imazamox application timing and rate on imazamox resistant wheat cultivars in the Pacific Northwest.* Weed Technology, 21(4), 895-899.

CDPR, California Department of Pesticide Regulation, Sacramento (2003) Public Report 200301, Clomazone.

Chakrabarti, R.P. K., Chakraborty, A., & Chowdhury, A., 2006.Degradation and Effects of Pesticides on Soil Microbiological Parameters-A Review. International Journal of Agricultural Research, 1: 240-258. DOI: 10.3923/Ijar.2006.240.258: Accessed online at URL: http://Scialert.Net/Abstract/?Doi=Ijar.2006.240.258 on 25/10/ 2016.

Che, F.S., Takemura, Y., Suzuki, N., Ichinose, K., Wang, J.M., & Yoshida, S., 1993. *Localization of target-site of the photoporphyrinogen oxidase-inhibiting herbicide S-23 142, in Spinaciaoleracea L. Z.*Naturforsch. C 48: 350-355.

Cieslik, L.F., Vidal, R.A., &Trezzi, M.M., 2013. *Environmental factors that affect the effectiveness of herbicides inhibiting accase: review*. Plant weed, v. 31, n. 2, p. 483-489.

Comoretto, L., et al., 2008. *Runoff of pesticides from rice fields in the Ile de Camargue (Rhône river delta, France): Field study and modeling.*Environ. Pollution, v. 151, n. 3, p. 486-493.

Cooper, J.F., 1996.*Adsorption, Desorption, and Degradation of Three Pesticides in Different Soils*. Arch. Environmental. Contamination. 30(1): 9-25.

Crop Watch, 2016. Institute of Agriculture and Natural Resources. Accessed online at: http://cropwatch.unl.edu/potato/injury_by_applicationPendimethalin on 28/10/2016.

Colquhoun, J., 2006. *Herbicide Persistence, Dissipation and Carryover*. Publication No. A3819. University of Wisconsin Extension, College of Agricultural and Life Sciences. Accessed online at URL: http://Corn.Agronomy.Wisc.Edu/Management/Pdfs/A3819. Pdf. On 04/10/2016

Coupland, D., 1987. *Influence of environmental factors on the performance of sethoxydim against Elymusrepens (L.).* Weed Research, 27(5): 329-336.

Crisp, P., &Gray, A.R., 1984. *Breeding old and new forms of purple heading broccoli*. Cruciferae New, 9: 17-18.

Daniel, C., Aniel, C., Parker, F., Simmons, W.,& Wax, L.M., 2005. *Fall and early preplant application timing effects on persistence and efficacy of acetamide herbicides*. Weed Technol. 19: 6-13.

Day, B.E, Jordan, L.S., & Jolliffe, V.A., 1968. *The influence of soil characteristics on the adsorption and phytotoxicity of simazine*. Weed Sci. 16: 209 - 213.

Das, A. C., Debnath, A., & Mukherjee, D., 2003. *Effect of the herbicides oxadiazon and oxyfluorfen on phosphates solubilizing microorganisms and their persistence in rice fields*. Chemosphere 53(5):217-221.

De-Candolle, A., 1885. *Origin of cultivated plants, p. 468.*

Dehne, H.W., 2004. *Safeguarding Production: Losses in Major Crops and the Role of Crop Protection*. Crop Protection 23:270–288.

Deng, W., Chen, L., Meng, Z., Wu, G., Zhang, R., 2010.*Review of non-chemical weed management for green agriculture Int*. Journal Agriculture and bio Eng; 3(4):52-60.

Dermiyati, S.K., & Yamamoto, I., 1997a. *Degradation of the herbicide halosulfuron-methyl in two soils under different environmental conditions*. J. Pestic. Sci. 22:282–287.

Dermiyati, S.K., & Yamamoto, I., 1997b. *Relationships between soil properties and sorption behavior of the herbicide halosulfuron-methyl in selected Japanese soils*. J. Pestic. Sci. 22:288–292.

Deuber, R., &Fornesier, J.B., 1980. *Herbicide experiment in garlic crops (Allium sativum, Res.* XIII Brazilian Congress of Herbicides and Herbs Dhaninhas, Bihia.

Dhiman, N.K, Nandal T.R., &Rajender, S., 2005.*Effect of Herbicides and their Impact on Cabbage Production*. Crop-Research. 30(1): 70-78.

Dillard, H.R., Bellinder R.R. & Shah D.A., 2004. *Integrated Management of Weeds and Diseases in Brassica Cropping System*. Crop-Protection*.* 23: (2): 160-175.

Dow Agrosciences, 2012.Goal 480 EC Label Dow AgroSciences (Pty) Ltd Pretoria South Africa.

Dyer, W.E., 2004. *Getting the Most from Soil-Applied Herbicides*. Extension Cropland Weeds, Weed Physiology, Montana State University-Bozeman.1-7.

Duggleby, R. G., McCourt, J. A. &Guddat, L. W., 2008. *Structure and mechanism of inhibition of plant acetohydroxyacid synthase*. Plant Physiol. Biochem. 46:309-324.

Duke, S. O., Lydon, J.,& Paul, R. N., 1989. *Oxadiazon activity is similar to that of p-nitro-diphenyl ether herbicides*. Weed Sci., v. 37, n. 2, p. 152-160.

Dziedzic, J.E., 1982. FMC 57020 hydrolysis study; FMC Corporation, Princeton, NJ, USA, unpublished report no.: P-0465 (FMC no.: CL 1.1.2/1). Final Addendum to the Draft

Assessment Report (DAR) – Initial Risk Assessment Provided by the Rapporteur Member State Denmark for the Existing Active Substance Clomazone.

Extoxnet: Extension Toxicology Network, 2000A. Pesticide Information Profile: Metolachlor Herbicides.

Extoxnet: Extension Toxicology Network, 2000B. Metolachlor Herbicide Profile 2/85.

Fausey, J. C., & Renner, K. A., 2001. *Environmental effects on CGA-248757 and flumiclorac efficacy/soybean tolerance*. Weed Sci., v. 49, n. 5, p. 668-674.

Feher, P.K., 1986. *The role of broccoli in nutritionHort Abs. 56(12), 1030*.

Ferhatoglu, Y., Barrett, M., 2006. *Studies of clomazone mode of action*. Pest BiochemPhysiol 85 (1): 7-14.

Filgueira, F.A.R., 2003. *New Manual of olericultura: modern agro-technology in the production and commercialization of vegetables*. Magazine and expanded. Viçosa: Federal University of Viçosa, p. 412.

FMC Corp., 2005. Command 3ME herbicide label, EPA Reg. No. 279-3158. FMC Corp., Philadelphia, PA.

Friesen, G., 1967. *The efficiency of barban as influenced by growth stages of wild oats and spring wheat*. Weeds, 15, 160-163.

Friesen, H.A., Born, W.H.V., Keys, C.H., Dryden, R.D., Molbery, E.S. & Simons, B. 1968. *Effect of time of application and dosage of dicamba on the tolerance of wheat, oats and barley*. Canadian Journal of Plant Science, 48: 213-215.

Gestel, C. N., Zak, C.J., & Tissue, D.T., 2007. *Soil temperature controls microbial activity in a desert ecosystem*. University of Western Sydney, Richmond, Australia.

Gomez, K.A.,& Gomez, A.A., 1984. *Statistical Procedures for Agricultural Research*. John Wiley and Sons, New York.

Gómez-Campo, C., & Gustafsson, M., 1991. *Germplasm of wild n=9 Mediterranean species of Brassica*. BotanikaChronika: 10, 429-434.

Govindra, S.V.M., Bhan, S. S., Tripathi, S.S., & Singh, D., 1984, *Comparative efficacy of herbicides in potato*. Indian J. Weed Sci., 16(1): 1-5.

Gray, A.R., 1982. *Taxonomy and evolution of broccoli (Brassica oleracea var. italica).* Econ. Bot., 36 (4): 397-410.

Gray, A.R., 1989. *Majoring in minor brassicas*. Science for growers, AFRC, Warwickshire: 2-3.

Green, R. E., &Obien, S. R., 1969. *Herbicide equilibrium in relation to soil water content.* Weed Sci. 18: 514 – 519.

Grey, T. L., Culpepper, A. S., & Webster, T. M., 2007a. *Residual herbicide dissipation from soil covered with low-density polyethylene mulch or left bare*. Weed Sci. 55:638–643.

Grey, T. L., Culpepper, A. S., & Webster, T. M., 2007b. *Autumn vegetable response to herbicides spring applied under polyethylene mulch*. Weed Technol. 21:496–500.

Grey, T. L., Vencill, W. K., Mantripagada, N.,& Culpepper, A. S., 2007. *Residual herbicide dissipation from soil covered with low-density polyethylene mulch or left bare*. Weed Sci. 55:638-643.

Grichar, W. J., Besler, B. A., & Brewer. K. D., 2003. *Purple nutsedge control and potato (Solanum tuberosum) tolerance to sulfentrazone and halosulfuron*. Weed Technol. 17:485-490.

Grichar, W., Dotray, P., & Langham, D., 2009. *Sesame (Sesamumindicum L.) response to preemergence herbicides*. Crop Protect. 28: 928-933.

Habimana, S., Karangwa, A., Mbabazi, P.M., &Nduwumuremyi, A., 2014. *International Journal of Social Sciences and Entrepreneurship*. Economics of Integrated Weed Management in Soybean (*Glycine Max*).

Harrison, H. F., &Peterson, J. K., 1999. *Effect of temperature and cultivar on the response of broccoli and collard (Brassica oleracea) to oxyfluorfen*. Weed Technol., v. 13, n. 4, p. 726-730.

Harrison, H.F. Jr., & Jackson, D.M., 2011. *Greenhouse assessment of differences in clomazone tolerance among sweet potato cultivars.* Weed Technol. 23: 504–505.

Harrison, H.F. Jr., Kousik, C.S.,& Levi, A., 2011. *Identification of Citrulluslanatusgermplasm lines tolerant to clomazone herbicide*. HortScience 46:684–687.

Harrison, H.F. Jr., & Farnham M.W., 2013. *Differences in tolerance of broccoli and cabbage cultivars to clomazone herbicide*. HortTechnology. 23:6-11.

Harrison, H.F.Jr., Farnham, M. W., & Jackson, D.M., 2015.*Tolerance of broccoli cultivars to pre-transplanting clomazone*. Crop Prot, 69:28-33.

Hartzler, B., 1997. *Absorption of Soil Applied Herbicides*. ISU Extension Agronomy.

Hatterman-Valenti, H. et al., 2011. *Environmental effects on velvetleaf (Abutilon theophrasti) epicuticular wax deposition and herbicide absorption*. Weed Sci., v. 59, n. 1, p. 14-21.

Hembree, K.J., 2004. *Minimizing offsite movement in permanent crop*. UCCE, Fresno country.

Herbst. K.A.,&Derr, J.F., 1990. *Effect of Oxyfluorfen Applied as Post-Emergence on Direct-Seeded Broccoli (Brassica Oleracea Var. Botrytis)*. *Weed Technology. Vol:* 4. 70–76.

Hopen, H.J., Hughes, R.L., & Michaelis, B.A., 1993. *Selectivity among cabbage (Brassica oleracea L.) cultivars by clomazone*. Weed Technol. 7:471–477.

Hopen, H.J.,1995. *Herbicides available for commercial cabbage producers during 1965-1994*. Horticulture Technology 10(1): 50-54.

Hoyt, G.D., Monks, D.W. & Monaco, T.J., 1994. *Conservation tillage for vegetable production*. HortTechnology 4(2):129-135.

Hwang, I.T. et al., 2004.*Protoporphyrinogen IX-oxidizing activities involved in the mode of action of a new compound N-[4-chloro-2-fluoro-5-{3-(2-fluorophenyl)-5-methyl-4.5 dihydroisoxazol- 5-yl-methoxyl-phenyl]-3,4,5,6tetrahydrophthalimide*. Pestic. Biochem. Physiol., v. 80, n. 2, p. 123-130.

Infante, M.L., & Morse, R.D 1995. *Integration of no-tillage and overseeded legume living mulches fortransplantedbroccoli production*.HortScience (in press).

Jacobs, J.M., Jacobs, N.J., Sherman, T. D., & Duke, S.0., 1991. *Effect of diphenyl ether herbicides on oxidation of protoporphyrinogen to protoporpyrin in organellar and plasma membrane- enriched fractions of barley*. Plant Physiol. 97, 197-203.

Jacobs, J.M., & Jacobs, N.J., 1993. *Porphyrin accumulation and export by isolated barley (HordeumvulgareL.) plastids: Effect of diphenyl ether herbicides*. Plant Physiol. 101: 1181 -1188.

Jablonska- Ceglarek, R., Ciubak, C., &Kolata, E., 1975. *Chemical weed control in irrigated late cauliflowers*. Biuletyn - Warzywniczy 17: 147-063.

Jeffery, E.H., Brown, A.F., Kurilich, A.C., Keck, A.S., Matusheski, N., Klein, B.P., &Juvik, J.A., 2003. *Variation in content of bioactive components in broccoli 16 (3): 323-330.*

Johnson, W.O., Kollman, G.E., Swithenbank, C., &Yih, R.Y., 1978. *RH-6201 (Blazer): a new broad-spectrum herbicide for postemergence use in soybeans.* J. Agric. Food Chem 26:285–286.

Johnson, W.C. III.,&Mullinix, B.G. Jr., 2002. *Weed management in watermelon (Citrulluslanatus) and cantaloupe (Cucumismelo) transplanted on polyethylene covered seedbeds*. Weed Technol. 16:860–866.

Johnson, W.C. III., &Mullinix, B.G. Jr., 2005. *Effect of herbicide application method on weed management and crop injury in transplanted cantaloupe (Cucumismelo) production*. Weed Technol. 19:108–112.

Johnson, W.S., 2002. *Water pH and its Effect on Pesticide Stability*. University of Nevada Cooperative Extension Fact Sheet, 2-38

Kathy Van Zyl, 2011. *South Africa Registered Herbicides Guide for Use on Cruciferous Crops.12-15.*

Keifer, D.W., 1989. *Tolerance of corn (Zeamays) lines to clomazone*. Weed Sci. 37:622–628.

Kiely, T., Donaldson, D., & Grube, A., 2004. *Pesticides Industry Sales and Usage: 2000 and 2001 Market Estimates*. EPA's Biological and Economic Analysis Division, Office of Pesticide Programs, and Office of Prevention, Pesticides, and Toxic Substances. http://www.epa.gov/pesticides.

Kikuti, A.L.P., & Marcos-Filho, J., 2007. *Physiological potential of cauliflower seeds and performance of plants in the field*. Brazilian Journal of Seeds 29: 107-113.

Klein, R.N., 2002. *Factors Affecting Soil-Applied Herbicides*. University Of Nebraska, Institute Of Agriculture and Natural Resources, Cooperative Extension Service. Accessed online at URL: http://Digitalcommons. Unl.Edu/Cgi /Viewcontent.Cgi? Article=2219&Context=Extensionhist 26/07/2017.

Kollman, W., &Segawa, R., 2000. *Pesticides Chemistry Database. Environmental Hazards Assessment Program*. California Department of Pesticide Regulation. Sacramento, CA.

Kortekamp,A., 2011. *Herbicides Applications: Problems And Considerations, Herbicides And Environment, (Ed.), ISBN: 978-953-307-476-4:* Available From: Http://Www.Intechopen.Com/Books/Herbicides-And-Environment/Herbicides-Applications-Problems-Andconsiderations. Accessed: 09 September 2016.

Krämer, W., Schirmer, U. (Ed). 2007. *Modern crop protection compounds*. Weinheim: Wiley-VCH Verlag, v. 1. p.409.

Krausz, R.F., Kapusta, G., & J.L. Matthews. 1998. *Sulfentrazone for weed control in soybeans (Glycine max).* Weed Technol 12:684–689.

Kulshrestha, G., & Singh, S.B., 1992. *Influence of soil moisture and microbial activity on pendimethalin degradation*. Bull. Enviro. Contam. Toxicol. 48, 269-274.

Lanini, W.T., 2006. *Herbicide Resistance Management*. University of California, Davis: 1-6.

Laviola, B.G., Lima, P.A., Júnior, A.W., Mauri, A.L., Viana, R.S.,& Lopes, J.C., 2006. *Effect of different types of substrates on germination and initial development of jiloeiro (Solanumgilo RADDI), light green cultivar*. Science and Agrotechnology 30: 415-421.

Leela, D., 1993. *Weedicides for vegetables*. Indian Horticulture 38 (2) :13-15.

Lee, D.J., Senseman, S.A., O'Barr, J.H., Chandler, J.M., Krutz, L.J., McCauley, G.N., & Kuk, Y.I., 2004. *Soil characteristics and water potential effects on plant-available clomazone in rice*. Weed Sci 52: 310-318.

Lee, H.J., Duke, M.V., & Duke, S.O., 1993. *Cellular localization of protoporphyrinogen-oxidizing activities of etiolated barley (Hordeurnvulgare L.) leaves: Relationship to mechanism of action of protoporphyrinogen oxidase inhibiting herbicides*. Plan/ Physiol. 102, 88, 1-889.

Leite, L. F. C. et al., 2003. *Estoquestotais de C orgânico e seuscompartimentosemargissolo sob floresta e sob milhocultivado com adubação mineral e orgânica*. R. Bras. Ci. Solo, v. 27, n. 5, p. 821-832.

Leslie, D.M., 2013.*Gross Margins for Selected Fruit, Vegetable and Root Crops for the Sugar Cane Belt in Fiji*.

Li, Z.H. et al., 2000. *Physiological basis for the differential tolerance of Glycine max to sulfentrazone during seed germination*. Weed Sci., v. 48, n. 3, p. 281-285.

Lin, Y.J. et al., 2000. *Photodegradation of the herbicides butachlor and ronstar using natural sunlight and diethylamine*. B. Environ. ContamToxicol**.**, v. 64, n. 6, p. 780-785.

Liu, S.Y., Shocken, M., Rosazza, J.P.N., 1996. *Microbial transformations of clomazone*. J Agr Food Chem 44, 313–319.

Liu, S., Chen, Y., Yu, H.,& Zhang, S., 2005. *Kinetic and mechanisms of radiation- induced degradation of acetochlor*. Chem. 59, 13-19.

Liu, W., Fang, Z., Liu. H., & Yang. W., 2002. *Adsorption of chloroacteanalide herbicides on soil and its components. Influence of clay acidity, humic acid coating and herbicide structure on acetanilide herbicide adsorption on homoinic clays*. J. Environ. Sci.14, 173 – 180.

Liu, W., 2005. *Sorption of Acetanilide Herbicides in Soils and its Interaction with Soil Properties Pesticides*. Science.1100–1113.

Malone, P.F., Villela, F.A., &Mauch, C.R., 2008. *Physiological potential of strawberry seeds and plant performance in the field*. Brazilian Journal of Seeds 30: 123-129.

Maoba, S., 2016. *Production Performance and Profitability Analysis of Small-Scale Layer Projects Supported through CASP in Germiston Region, Gauteng Province*. South African Journal of Agricultural Extension. Vol.44 n.1.

Matsumoto, H., Lee, J.J.,& Ishizuka, K., 1994. *Variation in crop response to protoporphyrinogen oxidase inhibitors*. Am. Chem. SOC., Washington, DC. Amer. Chem. SOC. Symp. Ser. 559, 120-132.

Martin, A.R., 2002. *Factors Affecting Soil-Applied Herbicides*. University Of Nebraska, Institute Of Agriculture and Natural Resources, Cooperative. URL: Accessed online at Http://Digitalcommons.Unl.Edu/Cgi/Viewcontent.Cgi?Article=2219&Context=Extensionhist on16/10/2016.

Massey, R.E., 2006. *Herbicide Application Rates: Risk Premiums with Environmental Implications Division of Applied Social Sciences University of Missouri: Southern Agricultural Economics*. Accessed online at http://Ageconsearch.Umn.Edu/Bitstream /35261/1/Sp06ma01.Pdf09/10/2016.

Mendes, K.F., Reis, M.R., Pereira, A.A., Nunes, A.R.S., Santos, C.E.M.,& Assis, A.C.L.P., 2013. *Sorption of Oxadiazon in soils cultivated in the Brazilliancerrado. Centre for Nuclear Enegy and Agriculture (CENA) Brazil*. Federal University of Vicosa, Brazil.

Menalled, F., & Dyer, W.E., 2005.*Data from soil applied herbicides.* Available online: http://scarb.MSU.montana.edu/cropweedsearch/ .Accessed: October 28, 2017.

Mervosh, T.L., Sims, G.K., & Ellsworth, T.R., 1995a. *Clomazone fate in soil as affected by microbial activity, temperature, and soil moisture*. J Agr Food Chem 43: 537-543.

Mervosh, T.L, Sims, G.K., & Ellsworth, T.R., 1995b.*Clomazone sorption in soils: incubation time, temperature, and soil moisture effects*. J Agr Food Chem 43 (8): 2295-2300.

Mervosh, T.L, Stoller, E.W., Simmons, F.W., Ellsworth, T.R., & Sims, G.K., 1995c. *Effects of starch encapsulation on clomazone and atrazine movement in soil and clomazone volatilization*. Weed Sci 43: 445-453.

Mills, J.A., Witt, W.W.,& Barrett, M., 1989. *Effects of tillage on the efficacy and persistence of clomazone in soybean (Glycine max).* Weed Sci 37(2): 217-222.

Miller, T., 2006. Washington State University, Department Of Crop and Soil Sciences. *Screening New Herbicides for Leafy Greens*. Final Report for 2005-2006. Report to U.S.D.A. Interregional Project: P67-71, P72-76.

Mo, W., & He, H., 2005. *Development of herbicidal-active materials from plants*, Huaxue Yu ShengwuGongcheng, 22(8), 7-9.

Monaco, T.J., Weller, S.C., & Ashton, F.M., 2002.*Weed Science: The Principles and Practices Management*. New York: John Wiley & Sons.

Montana State University Extension, 2013. Pesticide Performance and Water Quality. Accessed online at http://Store.Msuextension.Org/Publications/Agandnatural resources /MT201305AG.Pdf on14/10/2016.

Morse, R.D., 1995. *In-row soil loosening improves plant survival and yield of no-till cabbage and broccoli*. In Bradford, K.J. and Hartz, T.K., (eds).1993Proc. Fourth Nat. Symp.on Stand Establishment (April 23-26) Monterey, CA.

Mudge, C.R., Webster, E.P., Leon, C.T., & Zhang, W., 2005. *Rice (Oryzasativa) cultivar tolerance to clomazone in water seeded production*. Weed Technol. 19:907–911.

Muller, M.D., Poiger, T., &Buser, H., 2001.*Isolation and Identification of the Metolachlor Stereoisomers Using High Performance Liquid Chromatography, Polarimetric Measurements*. *Journal of Agricultural Food and Chemistry.* 49 (1): 39-51.

Nandal, T.R., Singh, A.K., & Arya, P.S., 1994. *Chemical weed control in onion (Allium cepa L.)*. Crop Research 8:532-536.

Nandal, T.R.,&Singh, S., 2005. *Economics of different weed control treatments in cauliflower*. Crop Research 29 (3):456-457.

Nandihalli, U.B., & Duke, S.0., 1993. *The porphyrin pathway as a herbicide target site*. Am. Chem. Soc., Washington, DC. Amer. Chem. SOC. Symp. Ser. 524,62-78.

Nkosi, T., &Claasen, L., 2016. Accessed online at Http:// Www. Financial mail. Co.Za/ Fmfox/2016/03/10/Cauliflower-Sales-A-Head-For-Figures 18/09/2016.

Noakes, T., 2014. Accessed online at http://Detopic.Crosslifter.Co/Real-Meal-Revolution. Pdf. 18/10/ 2016.

Norsworthy, J., 2006. University of Arkansas, Department Of Crop and Soil Sciences. Screening New Herbicides for Leafy Greens. Final Report for 2005-2006. Report to U.S.D.A.*Interregional Project:* P42-47.

Nuez, F., Gómez Campo, C., Fernández de Córdova, P., Soler S., &Valcárcel, J.V. 1999. *Collection of Similarities of Cauliflower and broccoli*. National Institute of Investigation and Technologist. Agrarian and Alimentary Madrid pg 120.

Owis, A. I., 2015.Broccoli:*The Green Beauty*: A Review J. Pharm. Sci. & Res. Vol. 7(9), 2015, 696-703.

Patel, C.L., Patel, Z.G., & Patel, R.B., 1983. *Integrated weed management in Onion bulb crops*. Indian Journal of Weed Science 15:7-11.

Patel, T.U., Patel, C.L., Patel, D.D., Thanki, J.D., Patel, P.S., &Jat, R.A., 2011. *Effect of weed and Fertilizer management on weed control and productivity of onion (Allium cepa).* Indian J. Agron., 56(3): 267-272.

Pliny, C. P. S., 1855. *The natural history of Pliny*. (Translated by John Bostock and H.T. Riley). 6 vol.

Prather, T.S., 1996. *Determining the economic impact of weed control in iceberg lettuce using varied rates of kerb in combination with hand hoeing, p.219-225*. In: Annu. Rpt.Iceberg Lettuce Advisory Board, Salinus, Calif.

Price, C.E., 1983. *The effect of environment on foliage uptake and translocation of herbicides*. In: A.O.A. Biologists. (Ed.). *Aspects of applied biology 4: Influence of* *environmental factors on herbicide performance and crop and weed biology. Wellesbourne*: The Association of Applied Biologists, v. 4. p. 157-169.

Price, A.J. et al., 2004.*Physiological behavior of root-absorbed flumioxazin in peanut, ivyleafmorningglory (Ipomoea hederacea), and sicklepod (Senna obtusifolia)*. Weed Sci., v. 52, n. 5, p. 718-724.

Qasem, J.R., 1992. *Suggested strategy for weed control. The First Arab Symposium for Weed Control in Orchards and Vegetable Fields*. Federation of the Arab Scientific Research Councils. 11-13 October 1992. Amman- Jordan.

Qasem, J.R., 2003. *Weeds and their Control*. University of Jordan Publications, Amman, Jordan, 628pp.

Qasem, J.R., 2007.*Weed Control in Cauliflower (BrassicaoleraceaVar Botrytis L.) With Herbicides*. Crop Protection. 26: 1010–1022.

Qasem, J.R., 2011. Herbicides Applications: Considerations for Herbicides, Environment and Herbicides Applications (Ed.), ISBN: 978-953-307-476-4: Accessed Online: http://Www.Intechopen.Com/Books/Herbicides-And-Environment/Herbicides-Applications-Problems-And-considerationson 19/11/2017

Quayle, W.C., Oliver, D.P., &Zrna, S., 2006. *Field dissipation and environmental hazard assessment of clomazone, molinate, and thiobencarb in Australian Rice Culture*. J Agr Food Chem. 54: 7213– 7220.

Sandhu, K.S., Hira, N.S.,& Randhawa, K.S., 1982. *Efficacy of different herbicides for weed control in cauliflowe*r. Pesticides 16 (10): 28-30.

Rao, V.S., 1999. *Principles of weed management*. Second Edition. Oxford and IBH Publishers Company Private Limited, New Delhi: 71-81.

Rao, V.S., 2002. *Principles of Weed Science*. 2nd Edition. Science Publishers Inc., Enfield.

Reinhardt, C.F. & Nel, P.C., 1984. *Die rol van sekereomgewingsfaktore by alachloraktiwiteit*. S. Afr. J. Plant Soil 1, 17 - 20.

Reinhardt, C.F., & Nel, P.C., 1989. *Importance of selected soil properties on the bioactivity of alchlor and metolachlor*. S. Afr. J. Plant Soil 6: 120 - 123.

Reinhardt, C.F., & Nel, P.C., 1990. *Importance of Selected Soil Properties on the Bioactivity of Metolachlor.* AfricaJournal Plant Soil 7: 99 - 107.

Rice, E.L., 1983. *Pest Control with Nature's Chemicals: Allelochemics and Pheromones in Gardening and Agriculture*. The University of Oklahoma Press, Oklahoma. Publishing Division of the University. Norman, Oklahoma.

Ritter, R.L., & Coble, H.D., 1981. *Influence of temperature and relative humidity on the activity of acifluorfen*. Weed Sci., v. 29, n. 4, p. 480-485.

Ross, M.A., &Lembi, C.A., 1999. *Applied Weed Science*. 2nd Edition. Prentice-Hall Inc. New Jersey 07458.

SAS Institute. 2003. SAS Version 9.1 for windows. SAS Institute, Cary, North Carolina.

Sato, R., Yamamoto, M., Shibata, H., Oshio, H., Harris, E.H., Gillham, N.W., & Boynton, J.E., 1994. Characterization of a Protox mutant of *Chlamydomonasreinhardrii*resistant to Protox inhibitors. Amer. Chem. SOC. Washington, DC. ACS Symp. Ser. 559, 91- 104.

Scherder, E.F., Talbert, R.E. & Clark, S.D., 2004. *Rice (Oryzasativa) cultivar tolerance to clomazone*. Weed Technol. 18:140–144.

Schocken, M.J., 1997. *Review: Microbial synthesis of agrochemical metabolites*. J Industrial MicrobiolBiotechnol 19: 392-400.

Scott, J.E., & Weston, L.A., 1992. *Cole crop (Brassicaoleracea) tolerance to clomazone*. Weed Sci. 40:7–11.

Scott, J.E., Weston, L.A., & Jones, R.T., 1995. *Clomazone for weed control in transplanted cole crops (Brassicaoleracea).* Weed Sci. 43:121–127.

Serage, T.I., 1993. *Effects of overseeded legume living mulches and tillage on weed suppressionand broccoli yield*. MS Thesis, Virginia Polytech. Inst. and State Univ., Blacksburg, VA.

Senseman, S.A. 2007. Herbicide handbook, 9th ed. Weed Science Society of American, Champaign, IL, pp. 76–78.

Sharma, S.R., 2004. *A Review of Hybrid Cauliflower Development:* Journal of New Seeds*. Vol* 6.1-4**.**

Sherman, T.D., Becerril, J.M., Matsumoto, H., Duke, M.V., Jacobs, J.M., Jacobs, N.J., & Duke, S.0., 1991. *Physiological basis for differential sensitivities of plant species to protoporphyrinogen oxidase-inhibiting herbicides*. Plant Physiol. 97,280-287.

Sikkema, P.H., Shropshire, C.,&Soltani. N., 2006. *Effect of clomazone of various market classes of dry beans*. Crop Protection 26:943–947.

Sikkema, P.H., Soltani, N., & Robinson, D.E., 2007.*Responses of Cole Crops to Pre-Transplant Herbicides*. *Crop Protection:* 10.1016.

Singh, H.P., Batish, D.R., &Kohli, R.K., (eds.). (2006). Weed Management Handbook. The Haworth Press, USA. pp. 892.

Smith, L.B., & King, G.J., 2000.*The distribution of BoCAL-a alleles in Brassica oleracea is consistent with a genetic model for curd development and domestication of the cauliflower*. Molecular Breeding, 6: 603-613.

Snogerup, S., Gustafsson, M., &Bothmer, V.R., 1990. Brassica sect. *Brassica (Brassicaceae): 1. Taxonomy and variation*. Willdenowia, 19: 271-365.

Soltani, N., Nurse, R.E., Shropshire, C., &Sikkema, P.H., 2009. *Effect of Halosulfuron applied preplant incorporated, preemergence, and postemergence on dry bean*. Weed Technol. 23: 535–539. doi:10.1614/WT-09-047.1.

Soltani, N., Shropshire, C., &Sikkema, P.H., 2012a. *Response of dry beans to halosulfuron applied postemergence*. Can. J. Plant Sci. 92: 723–728.

Soltani, N., Nurse, R.E., Shropshire, C., &Sikkema, P.H., 2012b. *Weed control, environmental impact and profitability of preplant incorporated herbicides in white bean*. Am. J. Plant Sci. 3: 846–853.

Soltani, N., Nurse, R.E., Shropshire, C., &Sikkema, P.H., 2013b. Weed *management in white beans with postemergence herbicide tankmixes*. Can. J. Plant Sci. 93: 669–674. doi: 10.4141/ cjps2012-273.

Soltani, N., Nurse, R.E., Shropshire, C., &Sikkema, P.H., 2014a. *Weed control in white bean with various halosulfurontankmixes*. Adv. Agri. 2014:1 –7. doi:10.1614/WT-03-043R3.

Soltani, N., Nurse, R.E., Shropshire, C., &Sikkema, P.H., 2014b. *Weed control with halosulfuron applied preplant incorporated, preemergence or postemergence in white bean*. Agri. Sci. 5: 875–881.

Song, K., Osborn, T.C., &. Williams, P.H., 1988. *Brassica taxonomy based on nuclear restriction fragment length polymorfism (RFLPs).2. Preliminary analysis of subspecies within B. rapa (syn. campestris) and B. oleracea*. Theoretical and Applied Genetics, 76: 593-600.

Song, K., Osborn, T.C., & Williams, P.H., 1990. *Brassica taxonomy based on nuclear restriction fragment length polymorfism (RFLPs). 3. Genome relationships in Brassica and related genera and the origin of B. oleracea and B. rapa (syn. campestris).* Theoretical and Applied Genetics, 79: 497-506.

Sonnenberg, P.E.,& Silva, N.F., 2005. *Weed interference in the transplanted cabbage crop*. PesqAgropec Trop. 35: 9-11.

Sotler, M., 1999. *The economic of cabbage and cauliflower growing*. Sodobnokmetiystvo 32 (11): 547-549.

South Africa Herbicide Guide, 2013. South Africa Herbicide Guide Book for Herbicides. 4-18.

Staub, J., Crubaugh, L., Baumgartner, H., &Hopen, H., 1991. *Screening of the cucumber germplasm collection for tolerance to clomazone herbicide*. Cucurbit Crop Genet. Rpt. 14:22–24.

Sturtevant, E. L., 1919. *Sturtevant's notes on edibleplants*. Edited by U.P. Hedrick. N.Y.Dept. Agr., Ann. Rep. Vol.2 (2): p. 686.

Su, S., 2006. *Crop injury from herbicides and its prevention in China*. XiandaiNongyao, 5(4), 1-4, 12.

Talbert, R.E., 2000.***A** Proposal to Standardize Soil/Solution Herbicide Distribution Coefficients*.Weed Science. 48: 74-90.

Taylor Lovell, S., Wax, L.M., & Nelson, R., 2001.Phytotoxic *Effect and Yield of Soybean (GlycineMax) Varieties Sprayed with Sulfentrazone and Flumioxazin Herbicides*. *Weed Technology.* 15, 90–105.

Taylor-Lovell, S., 2002. *Effects of Moisture, Temperature, and Biological Activity on the Degradation of Isoxaflutole in Soil*. J. Agric. 50(20): 5620-5639.

TenBrook, P.L., &Tjeerdema, R.S., 2006. *Biotransformation of clomazone in rice (Oryza sativa) and early watergrass (Echinochloaoryzoides).* PesticBiochemPhys 85(1): 38-45.

Thompson, W. M.,& Nissen, S. J., 2002. *Influence of shade and irrigation on the response of corn (Zeamays), soybean (Glycinemax), and wheat (Triticumaestivum) to carfentrazone-ethyl*. Weed Technol., v. 16, n. 2, p. 314-318.

Tomco, P.L., &Tjeerdema, R., 2012. *Photolytic versus microbial degradation of clomazone in a flooded California rice field soil*. Pest ManagSci 68(8): 1141-1147

Torstensson, L., 2007.*Effect of Biobed Composition, Moisture, and Temperature on the Degradation of Pesticides*.Journal Agriculture. 5718-5738.

Trader, B. W., Wilson, H. P.,& Hines. T. E., 2007. *Halosulfuron helps control several broadleaf weeds in cucumber and pumpkin*. Weed Technol. 21:966-971.

Umeda, K., 1998. *Weed control in melons using preemergence and postemergence herbicides*. Proc. West. Soc. Weed Sci. 51:74.

Umeada, K., 2000. *Screening new herbicides for weed control in head and leaf lettuces and broccoli*.

Umeda, K., &Murrieta, Jr., G.G., 1998.*Vegetable ReportPostemergence Herbicide Weed Control in Cole Crops, College ofAgriculture*;The University of Arizona. Publication az1101, pp. 1–2.

US EPA (2007) Clomazone summary document: Registration review. http://www.epa.gov/oppsrrd1/registration_review/clomazone/clomazone_summary.pdf

Vasilakoglou, I.B., Eleftherohorinos, I.G.,&Dhima, K.B., 2000. *Activity, adsorption and mobility of three acetanilide and two new amide herbicides*. Weed Res. 41, 535 - 546.

Wagner, G., &Nadasy, E., 2006. CommunAgricApplBiol Sci. 2006; 71(3 Pt A):809-13.

Weaver, S. E., 1984. *Critical period of weed competition in three vegetable crops in relation to management practices*. Weed Res. 24:317-325.

Weber, J.B., & Peter, C.J., 1982. *Adsorption, bioactivity, and evaluation of soil tests for alachlor, acetochlor, and metolachlor*. Weed Sci. 30, 14 - 20.

Weber, J.B., 2000. *A Proposal to Standardize Soil/Solution Herbicide Distribution Coefficients*. Weed. Science. 48: 70-90.

Webster, T. M., 2006. *Weed survey: southern states: vegetable, fruit, and nut crops subsection*. Proc. South. Weed Sci. Soc. 59:260-277.

Wehtje, G.R., Gilliam, C. H., & Hajek, B.F., 1993. *Adsorption, desorption, and leaching of oxadiazon in container media and soil*. HortSci. 28(2):126128.

Whitwell, J.D., Senior, D., &Jones, A.G., 1981. *Weed control programmesfor transplanted early summer cauliflower*. In: Proceedings of aConference: Crop Protection in North Britain, Dundee, 1981.Agriculture Development Advisory Service, Stockbridge HouseExperimental Horticulture Station, Selby, Yorks YO8 0TZ, UK, pp. 313–318.

Wichert, R.A. et al., 1992. *Temperature and relative-humidity effects on diphenylether herbicides*. Weed Technol., v. 6, n. 1, p. 19-24.

Williams, M., 2003. Mechanical Weed Control. The Vegetable Farmer, ACT Publishing, Maidstone, UK, 20-30.

Wills, G.D., &Mcwhorter, C.G.,1981. *Effect of environment on the translocation and toxicity of acifluorfen to showy crotalaria (Crotalariaspectabilis)*. Weed Sci., v. 29, n. 4, p. 397-401.

Wilson, D.E., Nissen, S.J., & Thompson, A., 2002. *Potato (Solanumtuberosum) variety and weed response to sulfentrazone and flumioxazin*. Weed Technol 16:567–574.

Wilson, R.G., 2002. *Factors Affecting Soil-Applied Herbicides*. University of Nebraska, Institute of Agriculture and Natural Resources, Cooperative Extension Service:Http://Www.Jkuat.Ac.Ke/Campuses/Kigali/WpContent/Uploads/2014/06/My-Publication-4.Pdf: Http://Www.Weeds.Iastate.Edu/ .Accessed: 17/10/ 2016.

Ying, G.,& Williams, B., 1999. *The degradation of oxadiazon and oxyfluorfen by photolysis*. J. Environ. Sci. Health, Part B, v. 34, n. 4, p. 549-567.

Ying, G., &Williams, B., 2000. *Laboratory study on the interaction between herbicides and sediments in water systems*. Environ. Pollution, v. 107, n. 3, p. 399-405.

Zanatta, J.F. et al., 2008. Teores de água no solo e eficácia do herbicidafomesafen no controlede*Amaranthushybridus*. Planta Daninha, v. 26, n. 1, p. 143-155.

Zanella, R., Primel, E.G., Gonçalves, F.F., Martins, M.L., Adaime, M.B., Marchesan, E., &Machado, S.L.O., 2008. *Study of the degradation of the herbicide clomazone in distilled and in irrigated rice field waters using HPLC_DAD and GC-MS*. J BrazChemSoc 19 (5): 987-995.

Zaragoza, C., 2003.*Weed Management in Cole Crops*. FAO Plant Production and Protection Paper 120 Add. Agriculture Department, Food and Agriculture Organization of the United Nations, Rome, Italy.

Zhang, W., Webster, E.P., Blouin, D.C. &Linscombe, S.D., 2004. *Differential tolerance of rice (Oryzasativa) varieties to clomazone*. Weed Technol. 18:73–77.

Zimdahl, R., 1980. *Weed Crop Competition, a Review*. International Plant Protection Center. Oregon State University. Corvallis.

Zimdahl, R.L., & Clark, S.K., 1982. *Degradation of three acetanilide herbicides in soil*. Weed Sci. 30: 545-548.