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Chemical weed control in garlic (*Allium sativum* L.) in Dongola Locality, Northern State, Sudan

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Article history: Received: March 2015
Accepted: June 2015

Abstract:

Weeds constitute one of the major biotic constraints that limit production of garlic (*Allium sativum*L.) in Sudan. A herbicides experiment in garlic was conducted during two consecutive winter seasons of the years 2011/2012 and 2012/2013 at the demonstration farm of Faculty of Agricultural Sciences- El Selaim-Dongola University-Sherg Elnil Unit-Dongola Locality, Northern State-Sudan to determine the magnitude of yield losses due to weed competition and to evaluate the activity and selectivity of the pre-emergence herbicides oxyfluorfen as two formulations (Pilargola 20% EC and Hadaf 24% EC) each at 0.24, 0.30 and 0.36 kg. a.i/ha; and pendimethalin (Stomp 500 EC) at 1.2, 1.5 and 1.8 kg. a.i/ha, in controlling weeds in garlic. Weeded and unweeded checks were included for comparison. The weed flora in the experimental site consisted of grassy and broad-leaved weeds. The two formulations of oxyflurofen and pendimethalin at their all rates gave consistent and excellent control of graminae weeds throughout the growing season. The two formulations of oxyflurofen gave satisfactory control of broad-leaved weeds, while the herbicide pendimethalin displayed poor to moderate activity. Results obtained showed that within the three herbicides the best grassy and broad-leaved weeds control was achieved by the herbicide oxyflurofen asHadaf. A significant weed controlwasachievedin terms of total weed biomass reduction with all herbicides treatments. The better total weed biomass reduction was achieved by the highest rate of pendimethalin (1.8 kg a.i./ha). In general, the herbicides had an excellent and lasting effects on the control of weeds, but the performance of these herbicides was greatly affected by the presence of the resistant weeds including *Cynodon dactylon* (L.) Pers., *Cyperus rotundus* L., *Convolvulus arvensis* L. and *Rhynchosia memnonia* (Del.) DC. Combined analysis of both winter seasons data indicated that unrestricted weed growth significantly reduced garlic yield by 36.08%. This reduction in garlic yield was due effect of weeds on various yield components. The combined analysis of both winter seasons data reported that, all herbicides treatments significantly increased garlic bulb yield, which varied from 21.95% to 57.14%. The increase in garlic bulb yield as a result of the treatments of the herbicides mainly due to an increase in number of cloves bulb and increased bulb weight. The combined analysis of both winter seasons data indicated that, within all

herbicides the best garlic bulb yield was achieved by the highest rate of pendimethalin at 1.8 kg. a.i/ha, and gave bulb yield comparable to weed free full season treatment. Based on these results, it can be concluded that, the effectiveness of the herbicide pendimethalin at 1.8 kg. a.i/ha, against weeds and its high selectivity in garlic, make this herbicide possible candidates for the control of weeds in garlic in the Northern State, Sudan. A significant increase due to herbicides treatments was also found in bulb weight (g).

Keywords: Herbicides; pre-emergence; stomp, pilargola and hadaf.

Introduction

The vast arable land, reasonable supply of irrigation water and variable climatic conditions, which ensure production of a wide range of crops, makes Sudan the proper candidate for solving food and feed problems on the international level. However, factors limiting crop regional production in Sudan are many, among them weed competition is the most important (Mahgoub, 2002). Garlic (Allium sativum L.) (Amaryllidaceae) is an important cash vegetable crop in the Northern and Nile States of the Sudan, where its production is favoured by the relatively longer and cooler winter season and availability of irrigation water. Recently, due to the implementation of free market agricultural policies, the area under garlic increased because returns from this crop are more than returns from other traditionally grown horticultural and field crops (Nourai, 1994 and Mohamed and Abdalla, 1997).

It was realized that the major constraint to the production of garlic in the Sudan is weeds. Garlic requires nearly perfect weed control because it emerges slowly and its short vertical leaves never form a canopy. Therefore, it is considerably weaker competitor than most crops. The magnitude of yield losses due to weeds in garlic ranged from 11.8% to 52.7% (Fischer et al., 2000 andAmel, 2003).

Until lately, weeds were not a serious constraint to crop production in northern Sudan. However, use of uncertified seeds, animal grazing and flooding of the River Nile led to spread of some serious annual weeds, including Sorghum arundinaceum (Dew.) Stapf., Sinapis arvensis L. and Chenopodium album L., throughout the Northern State (Bedry and Abbas, 2011 and Mohamed, 2012).

Recently, weeds became one of the main constraints in crop production in the Northern State and elsewhere in the Sudan. They reduce yield directly, through competition, parasitism and allelopathy or, indirectly, through hindering cultural and harvest practices and indirectly interfere with the use of land and water resources and adversely affect human welfare (Nasr Eldin, 2009; Mohamed and Elamin, 2011 and Mohamed, 2012b).

Farmers in the Sudan specially in the Northern State remove the weeds in garlic by repeated hand weeding for fodder to their livestock. Hand weeding is a labour intensive operation and therefore expensive, time consuming, and moreover labour has become scarce. The yield losses are mainly due to delayed weeding, or insufficient weed control. Weeds emerge before or along with garlic from the weed seed bank already present in the soil. They can smother the crop because of its low competitive ability during the early stages of growth. To eliminate the early competition of weeds, herbicides can be of great potential value (Mohamed and Abdalla, 1997 and Zebeir, 2013).

In developing countries manual weeding is the most common method of weed control but in many instances the available labour is unable to remove weeds from vast areas of land during critical periods, thus, the use of herbicides is a necessity (Mohamed and Hamada, 2011). Herbicides constitute a new and highly efficient method for controlling weeds, increasing yields and reducing labour in crop production (Mohamed, 2012a and Mahgoub et al., 2013). In Sudan the pre-emergence application of the herbicides oxadiazone, oxyfluorfen and pendimethalin was quite effective in controlling annual weeds in garlic (Mohamed and Abdalla, 1997). This research was therefore, carried out to determine the magnitude of yield losses due to weed competition and to evaluate the efficacy of the pre-emergence herbicides in controlling weeds and their selectivity in garlic crop.

Materials and Methods

Field experiment was conducted during two consecutive winter seasons (2011/12 and 2012/13) at the demonstration farm of Faculty of Agricultural Sciences-El Selaim-Dongola University-Sherg Elnil Unit-Dongola Locality-Northern State-Sudan-located within latitude 16° and 22° N, and longitude 20° and 32° E (Mohamed, 2012b). Dongola Locality which is a true desert with extremely high temperatures and radiation in summer, low temperature in winter, scarce rainfall and high wind speed. The mean maximum and minimum temperatures are 36.8 and 19.5°C, respectively. The climate is hyper arid with a vapour pressure of only 10.8 mb and a relative humidity of less than 20% . The soil of the the experimental site was sandy clay loam, with 59.67% sand, 20.33% silt and 20% clay (Damirgi and Al-agidi, 1982 and Zebeir, 2013).

The herbicides treatments were oxyfluoro-fen as two formulations Pilargola 20% EC and Hadaf 24% EC each at 0.24, 0.30 and 0.36 kg. a.i/ha and pendimethalin (Stomp 500 EC) at 1.2, 1.5 and 1.8 kg. a.i/ha. The treatments were arranged in a randomized complete block design (RCBD), with four replications. In each season, the experiment-tal site was disc ploughed, harrowed, leveled and divided to plots. Plot size was 3 × 2 m^2. Each plot was made of five rows. Sound mother bulbs of garlic, cultivar Baladi were selected for the trials and the bulbs were splitted just prior to cloves planting. The cloves were vertically hand planted (vertical placement) in holes 10 cm apart and 60 cm between rows on flat plots, each 3 × 2 m^2 in size. The date of planting was 18 November in both seasons. Nitrogen fertilizer, in the form of urea, was applied at the rate of 86 kg N/ha as two equal doses at 30 and 60 days after planting. Weeded and unweeded checks were included in the trials for comparison.

Aqueous solutions of the different herbicide treatments were applied pre-emergence using knapsack sprayer calibrated to deliver 254 l/fed. All other cultural practices were as Agricultural Research Corporation recommendations. Visual observations of phytotoxicity of the herbicides treatments on the crop were periodically observed.

The effects of treatments on weeds were assessed by counting the individual weed species at 4 and 8 weeks after sowing. This was done by randomly placing a 0.25 x 0.40 m quadrate at five places in each plot. Weeds inside each quadrate were identified and the individual weed species were counted. The percentages control of grassy and broad-leaved weeds, as compared with the unweeded control, for each treatment were calculated. Weed biomass weight was also determined.

The plants were harvested when they were fully mature. The number of plants/m^2 in each treatment was recorded. Also number of cloves/bulb and bulb

weight were determined from ten randomly selected bulbs from the three inner rows in each plot. At harvest area of 1 m^2 in each plot was harvested and air dried, then weighed and the bulb yield (t /ha) was calculated.

The mean collected data of both winter seasons was subjected to combined analysis of variance and the means were separated using Duncan's Multiple Range Test (DMRT) as described by Gomez and Gomez (1984).

Results and Discussion I

Visual observations showed that all herbicides treatments at their all rates showed no phytotoxicity symptoms on the crop. The treated plants had vigourous growth indicating that the herbicides used were selective for garlic.

The dominant weed species found at the experimental site were: *Tribulus terrestris* L., *Malva palviflora* L., *Eruca sativa* Mill., *Echium rauwolfii*Del., *Amaranthus viridis* L., *Chenopodium album* L., *Euphorbia aegyptiaca* Boiss. *Cynodon dactylon* (L.) Pers., *Cyperus rotundus* L., *Echinochloa colona* (L.) Link., *Trigonella hamosa* L., *Convolvulus arvensis* L. and *Rhynchosia memnonia* (Del.) DC.

Weeds compete garlic for water, nutrients, space and light. The competition in garlic is most severe because its buds sprout and grow slowly plus the fact that its cylindrical-upright leaves do not shade the soil to suppress weed growth (Mohamed and Abdalla 1997 and Mohamed, 2012b). In addition, warmer winter conditions in Northern Sudan also permit early establishment of weeds in garlic. Early weed interference usually reduces garlic bulb yield more than late germinating weeds (Mohamed and Abdalla (1997).

The weed flora in the experimental site consisted of grassy and broad-leaved weeds. The formulation of oxyfluorofen (Pilargola, Hadaf) and pendimethalin (Stomp) at their all rates gave consistent and excellent control of graminae weeds throughout the growing season. The two formulations of oxyfluorofen (Pilargola and Hadaf) gave satisfactory control of broad-leaved weeds, while the herbicide pendimethalin (Stomp) displayed poor to moderate activity against broad-leaved weeds (Table 1). I repeat the work previously done and published in Northern State because it was done in an other State and the edaphic factors and the climatic conditions which affect performance of soil-applied herbicides vary from State to an other and I used the same herbicide formulations of oxyfluorofen because they are sometimes re-evaluated in different countries and even within different locations within a country. Similar results were reported by Mohamed and Abdalla (1997) who said that the herbicides oxyfluorofen (Goal) and pendimethalin (Stomp) applied as pre-emergence treatments in garlic gave and maintained excellent control of grassy weeds, the herbicide oxyfluorofen (Goal) gave satisfactory control of broad-leaved weeds, while the herbicide pendimethalin (Stomp) displayed poor to moderate activity against broad-leaved weeds. Also these findings are in line with the result of Surrey (1996) and Bedry and Abbas (2011). Results obtained showed that within the three herbicides the better and highest percentage grassy and broad-leaved weeds control was achieved by the herbicide oxyfluorofen (Hadaf) at its all rates (Table 1).

A significant weed controlwasachievedin terms of total weed biomass reduction with all herbicides treatments as compared to weedy full season treatment (Table 2). The

better total weed biomass reduction was achieved by the highest rate of pendimethalin (Stomp) (1.8 kga.i./ha) (Table 2). These results are in conformity with the findings of Surrey (1996) and Mohamed and Elamin (2011). This significant reduction in weed biomass could be merely due to effectiveness of these herbicides in controlling weeds.

In general, the herbicides had an excellent and lasting effect on the control of weeds, but the performance of these herbicides was greatly affected by the presence of the resistant weeds, including *Cynodon dactylon* (L.) Pers., *Cyperus rotundus* L., *Convolvulus arvensis* L. and *Rhynchosia memnonia* (Del.) DC., because they are perennials that they are difficult to control by hand weeding or herbicides treatments. Similar findings were obtained by Mohamed and Abdalla (1997).

Combined analysis of both winter seasons data indicated that unrestricted weed growth significantly reduced garlic bulb yield by 36.08% compared to weed free full season treatment (Table 2). This reduction in garlic yield is due effect of weeds on various yield components. Similar findings were found by Mohamed and Abdalla (1997) who reported that unrestricted weed growth accounted for 22% and 26% loss in garlic bulb yield as compared with the weed free check. Also these results are in line with those obtained by Amel (2003). The presence of weeds reduced the number of plants/$m^2$and the number of cloves/bulb and reduced significantly bulb weight. The combined analysis of both winter seasons data indicated that, all herbicides treatments significantly increased garlic bulb yield, which varied from 21.95% to 57.14% over the weedy full season treatment. This result is in conformity with the findings of Surrey (1996); Mohamed and Abdalla (1997); Tewari *et al*., 1998 and Mukhtar *et al*., (2013). The increase in garlic yield as a result of the treatments of the herbicides mainly due to an increased number of cloves/ bulb and increased bulb weight. The combined analysis of both winter seasons data indicated that, within all herbicides the best garlic bulb yield was achieved by pendimethalin (Stomp) at 1.8 kg. a.i/ha, and gave bulb yield comparable to weed free full season treatment(Table 3). This rate is higher than the recommended rate of pendimethalin in garlic (1.2 kg. a.i/ha) because some factors affect the performance of this herbicide such as edaphic factors and microorganisms. Similar results were obtained by Surrey (1996) and Adekpe *et al*., (2007). These results have shown that early removal of weeds by herbicides enable the crop to maximize the use of the available resources and this reflect positively on good establishment for crop growth.

Based on these results, it can be concluded that, the effectiveness of the herbicide Stomp at 1.8 kg. a.i/ha, against weeds and its high selectivity in garlic, make this herbicide possible candidate for the control of weeds in garlic in the Northern State, Sudan. This is substantiated by the adverse effects of weeds on garlic coupled with scarcity of labor and its high cost. A significant increase due to herbicides was also found in bulb weight (g) (Tables 3). This result is in line with the findings of Mohamed and Abdalla (1997).

Conclousions

1- The dominant and prevalent weed species in the experimental site was broad-leaved weeds in the Northern State.

2- Within the three herbicides the better and highest percentage grassy and broad-leaved weeds control was achieved by the herbicide oxyfluorofen (Hadaf) at its all rates.

3- A significant weed controlwasachievedin terms of total weed biomass reduction with all herbicides treatments.

4- The better total weed biomass reduction was achieved by the highest rate of pendimethalin (Stomp) (1.8 kga.i./ha).

5- Unrestricted weed growth significantly reduced garlic bulb yield by 36.08%.

6- All herbicides treatments significantly increased garlic bulb yield, which varied from 21.95% to 57.14%.

7- Within all herbicides the best garlic bulb yield was achieved by pendimethalin (Stomp) at 1.8 kg. a.i/ha, and gave bulb yield comparable to weed free full season treatment**.**

Recommendations

Based on the above mentioned results I recommend the use of pendimethalin as Stomp 500EC at 1.8 kg. a.i/ha for pre-emergence weed control in garlic and followed by one supplementary hand weeding at 4 weeks after sowing to control the tolerant weeds.

Table 1: Effects of herbicides on weedsin garlic at 4 and 8 weeks after sowing during winter seasons (2011/ 2012) and (2012/ 2013), combined

Treatments	Herbicide rate Kg. a.i./ha	Percentage graminae weed control		Percentage broad leaved weed control	
		4 WA S*	8 WA S	4 WA S	8 WA S
Oxyfluorofen (Pilargola)	0.24	81	74	70	44
Oxyfluorofen (Pilargola)	0.30	87	81	74	54
Oxyfluorofen (Pilargola)	0.36	90	89	78	67
Oxyfluorofen (Pilargola)	0.24	91	89	76	53
Oxyfluorofen (Pilargola)	0.30	93	92	79	61
Oxyfluorofen (Pilargola)	0.36	96	94	82	75
Pendimethalin(Stomps)	1.2	90	88	42	21
Pendimethalin(Stomps)	1.5	93	94	51	32
Pendimethalin(Stomps)	1.8	97	96	66	34
Weed free full season	-	100	100	100	100
Weedy full season	-	0.00	0.00	0.00	0.00

WA S* = Weeks after sowing

Table 2: Effects of herbicides on weed biomass (g / m^2) in garlic at 4 and 8 weeks after sowing during winter seasons (2011/ 2012) and (2012/ 2013), combined

Treatments	Herbicide rate Kg. a.i./ha	Weed biomass (g / m^2)	
		4 weeks after sowing	8 weeks after sowing
Oxyfluorofen (Pilargola)	0.24	5.53b	6.30b
Oxyfluorofen (Pilargola)	0.30	4.30c	5.40bc
Oxyfluorofen (Pilargola)	0.36	3.67cd	4.43cd
Oxyfluorofen (Pilargola)	0.24	4.23c	5.37bc
Oxyfluorofen (Pilargola)	0.30	3.33cd	4.23cd
Oxyfluorofen (Pilargola)	0.36	2.77de	3.83de
Pendimethalin(Stomps)	1.2	3.00cde	4.07d
Pendimethalin(Stomps)	1.5	2.57de	3.40de
Pendimethalin(Stomps)	1.8	1.93e	2.77e
Weedy full season	-	7.77a	13.00a
Sig	-	*	*
C.V%	-	17.09	14.15
S.E	-	0.24	0.48

-Means with the same letters in the same column are not significantly different at 0.05 level of probability according to DMRT.

* = Significant at 0.05 robability level

Table 3: Effects of herbicides on yield and yield components of garlicduring winter seasons (2011/ 2012) and (2012/ 2013), combined

Treatments	Herbicide rate Kg a.i./ha	Number of plants/m^2	Number of cloves/bulb	Bulb weight (g)	Yield (t /ha)
Oxyfluorofen (Pilargola)	0.24	17.00a	8.10a	20.60f	3.50f
Oxyfluorofen (Pilargola)	0.30	17.33a	10.20a	22.00e	3.74e
Oxyfluorofen (Pilargola)	0.36	17.67a	10.03a	22.43de	3.81de
Oxyfluorofen (Pilargola)	0.24	17.33a	9.80a	22.13de	3.76de
Oxyfluorofen (Pilargola)	0.30	19.00a	10.10a	23.23cd	3.95cd
Oxyfluorofen (Pilargola)	0.36	17.33a	9.87a	23.80bc	4.04bc
Pendimethalin(Stomps)	1.2	16.67a	9.23a	23.20cd	3.95cd
Pendimethalin(Stomps)	1.5	18.33a	12.47a	24.43b	4.15b
Pendimethalin(Stomps)	1.8	16.33a	14.50a	26.53a	4.51a
Weed free full season	-	19.00a	17.87a	26.40a	4.49a
Weedy full season	-	16.33a	8.53a	16.90g	2.87g
Sig	-	NS	NS	*	*
C.V%	-	11.36	48.56	2.67	2.67
S.E	-	1.40	3.77	0.44	0.10

-Means with the same letters in the same column are not significantly different at 0.05 level of probability according to DMRT.

* = Significant at 0.05 probability level

NS = not significant at 0.05 probability level

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المكافحة الكيميائية للحشائش فى الثوم (*Allium sativum* L.) **بمحلية دنقلا–الولاية الشمالية–السودان**

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المستخلص:

تشكل الحشائش أحد المعوقات الحيوية الرئيسية التى تحد التوسع فى إنتاج الثوم (*Allium sativum* L.) فى السودان. أجريت تجربة مبيدات الحشائش فى الثوم خلال موسمين شتويين متعاقبين للعامين 2012/2011 و 2013/2012 فى المزرعة التجريبية لكلية العلوم الزراعية– السليم–جامعة دنقلا، وحدة شرق النيل، محلية دنقلا، الولاية الشمالية، السودان لتحديد مقدار حجم الفقد فى الإنتاجية الناجم من منافسة الحشائش ولتقييم فعالية وإختيارية مبيدات الحشائش المستعملة قبل الإنبثاق أوكسى فلوروفين فى صورتى بلارقولا وهدف 20% إى سى (أوكسى فلورفين) بمعدل 0.24 ، 0.30 و0.36 كجم مادة فعالة للهكتار لكل، و بنديميثالين 500 بمعدل 1.2 ، 1.5 و1.8 كجم مادة فعالة للهكتار لمكافحة الحشائش فى الثوم. تم تضمين معاملة نظيفة من الحشائش ومعاملة موبوءة بها للمقارنة. فلورا الحشائش فى موقع التجربة شمل الحشائش النجيلية وعريضة الأوراق. جميع جرعات صورتى أوكسى فلوروفين وبنديميثالين أعطى مكافحة ممتازة للحشائش النجيلية خلال موسم النمو.. مبيدات حشائش صورتى أوكسى فلوروفين أعطت مكافحة مقنعة للحشائش عريضة الأوراق، بينما مبيد حشائش بنديميثالين أعطى فعالية ضعيفة إلى متوسطة. أوضحت النتائج المتحصلة أن مبيد حشائش أوكسى فلوروفين فى صورة هدف كان من أحسن مبيدات الحشائش الثلاثة وأعطى أحسن وأعلى نسبة مكافحة للحشائش النجيلية وعريضة

الأوراق. مكافحة الحشائش معنوياً بجميع معاملات مبيدات الحشائش عبرت كنقصان فى الوزن الجاف الكلـــى للحشـــائش. أحسن نقصان فى الوزن الجاف الكلى للحشائش أنجز بالجرعة العالية لمبيد بنديميثالين (1.8 كجم مادة فعالـــة للهكتـــار). مبيدات الحشائش بصورة عامة لها تأثيرات ممتازة ونهائية فى مكافحة الحشائش، لكن أداء هذه المبيدات تأثر كثيراً بوجود الحشاتئش المقاومة مثل النجيل،السعدة، العليق والأدنة. أشار التحليل المشترك لبيانات ا لموسمين الشتويين إلى أن النمـــو غير المحدود للحشائش قلل معنوياً إنتاجية بصلة الثوم ب 36.08%. هذا النقص فى إنتاجية بصلة الثوم نجم مـــن تـــأثير الحشائش على مختلف مكونات الإنتاجية. أوضح التحليل المشترك لبيانات الموسمين الشتويين أن كل معاملات مبيـــدات الحشائش زادت معنوياً إنتاجية بصلة الثوم والتى تراوحت من 21.95% إلى 57.14%. الزيادة فى إنتاجية بصلة الثوم نتيجة معاملات مبيدات الحشائش ناجمة من زيادة عدد الفصوص فى البصلة والزيادة فى وزن البصـــلة. أشـــار التحليـــل المشترك لبيانات الموسمين الشتويين إلى أن من بين معاملات مبيدات الحشائش الجرعة العالية لمبيد بنديميثالين (1.8 كجم مادة فعالة للهكتار) حققت أحسن إنتاجية لبصلة الثوم و أعطت إنتاجية مشابهة للمعاملة النظيفة من الحشائش طول الموسم. على أساس هذه النتائج يمكن إستنتاج أن فعالية مبيد الحشائش بنديميثالين بمعدل 1.8 كجـــم مـــادة فعالـــة للهكتارضـــد الحشائش وإختياريته العالية فى الثوم، يجعل هذا المبيد مرشح ممكن لمكافحة الحشائش فى الثوم فى الولايـــة الشـــمالية، السودان. أيضاً وجدت الزيادة المعنوية فى وزن البصلة بالجم نتيجة معاملات مبيدات الحشائش.