ECONOMICS OF HERBICIDE WEED MANAGEMENT IN WHEAT IN ETHIOPIA

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ABSTRACT

Effective use of herbicides for the control of annual grass and broadleaf weeds in wheat (Triticum aestivum L.) was not a reality in Ethiopia, until in recent years. This study aimed at evaluating different post-emergence herbicides against annual grasses and broadleaf weeds in wheat for selection and incorporation into an integrated weed management (IWM) system. The study was conducted at Kulumsa Agricultural Research Centre main station, Bekoji and Lole farm fields. Treatments included herbicides, namely, Mesosulfron methyl+Idosulfuron methyl sodium (liquid) 1 l it ha⁻¹ a.i. Pyroxsulam (liquid) 0.5 l ha⁻¹ a.i. hand weeding twice (30-35 and 55-60 days after emergence (DAE)); and a weedy check. Among the annual grass weeds, Snowdenia polystachya, Avena fatua, Bromus pectinatus, Phalaris paradoxa and Setaria pumila; and most broad leaf weeds like Polygonum nepalense, Guizotia scabra, Galinsoga parviflora and Gallium spurium were controlled with herbicide efficacy ranging from 75 to 100%. Mesosulfron methyl +Idosulfuron methyl sodium, Pyroxulam and hand weeded twice plots out-yielded the weedy check by 63, 58 and 53%, respectively. Maximum wheat grain yield (5,184 kg ha⁻¹), biomass (12,808 kg ha⁻¹), thousand kernel weight (48.55) and hectoliter weight (74.2) were obtained due to the application of Mesosulfron methyl +Idosulfuron methyl sodium. In addition, the herbicide had a yield advantage over Pyroxulam, two hand weedings and the weedy check by 12, 21 and 63%, respectively. Application of Mesosulfron methyl +Idosulfuron methyl sodium (US$1,596.31 ha⁻¹) had the highest net field benefit compared to Pyroxulam (US$1,379.21 ha⁻¹), two hand weeding (US$1,126.7 ha⁻¹) and weedy check (US$574.1 ha⁻¹) by 13.6, 29 and 64%, respectively. Moreover, the herbicide was also economically profitable to farmers, providing a marginal rate of return (MRR) of 1,737%. Sensitivity analysis (MRR) also remained the most profitable even when the price of herbicide increased by 20%. Hence, Mesosulfron methyl +Idosulfuron methyl sodium at a rate of 1 l it ha⁻¹ is the best herbicide for the effective control of annual grasses and broad leaf weeds in wheat and can be used as one of the component in Integrated Weed Management Program (IWM) in wheat fields.

Key Words: Idosulfuron methyl sodium, Mesosulfron methyl, Triticum aestivum

RÉSUMÉ

l’utilisation efficace d’herbicides pour le contrôle d’herbe annuelle et de mauvaises herbes broadleaf dans le blé (Triticum aestivum L.) n’était pas une réalité en éthiopie, jusqu’à au cours des dernières années, cette étude visait du fait d’évaluer de différents herbicides de post-émersion contre les herbes annuelles et les mauvaises herbes broadleaf dans le blé pour la sélection et l’incorporation dans une administration de mauvaise herbe intégrée (IWM) le système. l’étude a été accomplie au centre de recherche agricole kulumsa la station principale, Bekoji et les champs de ferme Lole. les traitements ont inclus des herbicides, à savoir, le méthyle de mesosulfron le sodium de méthyle d’idosulfuron 1 (liquide) allumé ha⁻¹ a.i. pyroxsulam 0.5 l (liquides) ha⁻¹ main d’a.i. désherbant deux fois (30-35 et 55-60 jours après l’émersion (dae)); et un chèque malingre. Parmi les mauvaises herbes d’herbe annuelles, Snowdenia polystachya, Avena fatua, Bromus pectinatus, Phalaris paradoxa et Setaria pumila; et les plus larges mauvaises herbes de feuille comme Polygonum nepalense, Guizotia scabra, Galinsoga parviflora et le Gallium spurium ont été contrôlées avec l’effet d’herbicide aux limites de 75 à 100 %. Le méthyle de Mesosulfron que le sodium de méthyle d’Idosulfuron, Pyroxulam et la main désherbee complotent deux fois dehors - a produit
le chèque malingre par 63, 58 et 53 %, respectivement. La production de grain de blé maximum (5,184 kg ha$^{-1}$), la biomasse (12,808 kg ha$^{-1}$) et de poids d’hectolitre (74.2) a été obtenue en raison de l’application de méthyle Mesosulfron le sodium de méthyle d’Idosulfuron, Pyroxulam et la main désherbée conspirent deux fois dehors - a produit le chèque malingre par 63, 58 et 53 %, respectivement. La production de grain de blé maximum (5,184 kg ha$^{-1}$), la biomasse (12,808 kg ha$^{-1}$), un mille de poids cardinal (48.55) a été obtenue en raison de l’application de méthyle Mesosulfron le sodium de méthyle d’Idosulfuron. En plus, l’herbicide avait un avantage de production sur Pyroxulam, deux main weedings et le chèque malingre par 12, 21 et 63 %, respectivement. L’application de méthyle Mesosulfron le sodium de méthyle d’Idosulfuron (US$1,596.31 ha$^{-1}$) avait le plus haut avantage net de terrain comparé à Pyroxulam (US$1,379.21 ha$^{-1}$), deux main désherbante (US$1,126.7 ha$^{-1}$) et chèque malingre (US$574.1 ha$^{-1}$) par 13.6, 29 et 64 %, respectivement. e plus, l’herbicide était aussi économiquement profitable aux fermiers, en fournissant un taux marginal de retour (MRR) de 1,737 %. L’analyse de sensibilité (aMRR) est aussi restée le plus profitable même lorsque le prix d’herbicide a augmenté de 20 %.

Dorénavant, le méthyle de Mesosulfron le sodium de méthyle d’Idosulfuron à un taux de 1 allumé ha 1 est l’herbicide thebest pour le contrôle efficace d’herbes annuelles et de larges mauvaises herbes de feuille dans le blé et peut être utilisé comme une de la composante dans le Programme d’Administration de Mauvaise herbe Intégré (IWM) dans les champs de blé.

Mots Clés: le sodium de méthyle d’Idosulfuron, le méthyle de Mesosulfron, Triticum aestivum

INTRODUCTION

Ethiopia is the largest producer of wheat (Triticum aestivum) in sub-Saharan Africa. The current total area suited to wheat production in the country is estimated at over 1.6 million ha, with an average grain yield of 2.1 tonnes per hectare (CSA, 2012). Durum and bread wheat are the two major wheat varieties produced in the country, whose proportion in 1991 were about 60 and 40%, respectively (Eshetu and Zerihun, 2003). Durum and emmer wheat are indigenous to Ethiopia and have been cultivated since the prehistoric period in the highlands.

Weed interference is one of the most important, but less understood factors, contributing to lowering the yields of wheat (Hassan and Marwat, 2001). Weeds reduce yields of the crop, deteriorate the quality of farm produce, and trim down the market value of wheat. An estimated yield loss of about 10% in the less developed countries and 25% in the least developed countries is caused by weeds (Akobundu, 1987).

In Ethiopia, a yield loss of above 36.3% was recorded in wheat in uncontrolled plots (Rezene, 2005). Similarly, in a study of Avena abyssinica, Lolium temulentum L., Snowdenia polystachya and Phalaris paradoxa L. with bread wheat, yield losses of 48-86% were recorded by the maximum weed density of 320 weed seedlings per m$^2$ (Taye et al., 1996).

In Durum wheat, Convolvulus arvensis and Cyperus spp. pose significant yield losses. Besides, considerable yield losses of up to 60% have been recorded in irrigated wheat, due to Sorghum arundinacea, Cyperus esculentus, Cyperus rotundus, Portulaca oleracea, Corchorus olitorius and Sorghum arundinacea (Kassahun et al., 1998).

Bromus pectinatus and Snowdenia polystachya are weed species that recently became prominent in the affected cropping systems in Ethiopia due to a weed population shift, attributed primarily to continuous cereal cropping and frequent use of selective herbicides against previously common grass weeds, such as Avena fatua (Tanner and Giref, 1991; Amanuel et al., 1992; Rezene and Yohannes, 2003). This study was designed to evaluate different herbicides for the control of annual grasses and broadleaf weeds in wheat and to incorporate the best herbicide in an integrated weed management programme.

MATERIALS AND METHODS

The study was conducted at Kulumsa Agricultural Research Centre main station, Bekoji and Lole (Ego) farmers field during the main cropping season of 2011/12 and 2012/13. Kulumsa is situated in the main wheat belt of Ethiopia at an altitude of 2200 m.a.s.l, located in the north periphery of Asella town. It lies at 8°012'10"N
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and 39°092 11°E and receives mean rainfall of 832 mm. The mean minimum and maximum temperature is 10 and 23 °C, respectively.

Bekoji is found at 7°322.37°N and 39°152.21°E, with an altitude of 2780 m.a.s.l and receives average rainfall of 1066 mm; and the mean minimum and maximum temperatures of 9.6 and 24 °C, respectively. Dominant soils in these areas are Luvisol and Nitosol, respectively.

Treatments included post-emergence herbicides, namely, Pyroxsulam (liquid) 0.5 lit ha⁻¹ a.i., and Mesosulfron methyl +Idosulfuron methyl sodium (liquid) 1 lit ha⁻¹ a.i.; two hand weedings, and a weedy check as the control. Herbicides were applied at 30-35 days after emergence (DAE); and hand weeding was done 30-35 and 55-60 DAE. The required quantity of the herbicide was calculated and measured out into a manual knapsack sprayer, and filled with water to a volume of 200 lit for each herbicide treatment. All the necessary agronomic practices were applied equally for all treatments.

Dendea bread wheat variety was used for the trials at different locations, at a seeding rate of 150 kg ha⁻¹, by row planting; and 100 kg ha⁻¹ Di Ammonium Phosphate (DAP) and 50 kg ha⁻¹ Urea fertilisers were applied at the time of sowing for all the treatments, in plots of 5 m by 4 m. The study was laid out in randomised complete block design (RCBD), in three replications.

Parameters measured included plant height, number of tillers, spike length, weed count before, two and four weeks after herbicide application, general weed control visual assessment using a scoring scale of 1-5 scale; 1 = Complete eradication; 2 = effective destruction; 3 = proper reduction in growth and population; 4 = reduced growth and population; and 5 = healthy wheat plots. After harvesting, dry weed biomass, crop biomass, grain yield, thousand kernel weight (TKW), and Hector liter weight (HLW) were measured by taking their weights and counting the seed by a seed counter machine.

All data were subjected to statistical analysis using Proc GLM procedure in SAS (SAS Institute Inc, 1994). Comparisons among treatments, with significant differences, were based on LSD test at P<0.05. Linear correlation was used to determine the association between grain yield and yield components, using Minitab Software.

Economic data were collected to compare the economic advantage of each herbicide in different treatments. These included variable input costs and costs for the herbicides and labour during the execution of the experiment. Costs of herbicides were obtained from pesticide companies and local distributing agencies.

Based on the data obtained from both locations, economic analysis was computed using partial budget analyses, Marginal Rate of Return (MRR) and sensitivity analysis even when herbicide cost was increased by 20% (CIMMIT, 1988). The following formulae were used to compute partial budget and marginal rate of return (MRR) analysis, respectively.

Net field benefits (NBs) = Gross field benefits (GB) - Total Variable costs (TVC) and

\[ \text{MRR} = \frac{\text{DNI}}{\text{DIC}} \]

Where:  
MRR = the marginal rate of return;  
DNI = difference in net income compared with control; and  
DIC = difference in input cost compared with control.

RESULTS AND DISCUSSION

Efficacy of herbicides. All the treatments except untreated weedy check, were effective in controlling the target annual grass weeds like Snowdenia polystachya, Avena fatua, Bromus pectinatus, Phalaris paradoxa, Setaria pumila; and broad leaf weeds like Gizotia scabra, Galinsoga parviflora, Gallium spurium and Polygonum nepalense, at an efficacy rate of 75-100%. Effectiveness of control of S. polystachya by Mesosulfron methyl +Idosulfuron methyl sodium, Pyroxulam and two hand weeding was 100, 75 and 100%, respectively (Table 1). For that of A. fatua, Mesosulfron methyl +Idosulfuron methyl sodium, Pyroxulam and two hand weedicings controlled the weeds at efficacy rate of 87, 88 and 100%, respectively, Phalaris pectinatus was controlled by Mesosulfron methyl +Idosulfuron methyl sodium, Pyroxulam and two hand weeding at 100% efficacy. Whereas, Bromus pectinatus was controlled at 85, 100 and 100% efficacy, respectively (Table 1). Rezene et al.
| Locations | Scientific name of weed species | Mesosulfron methyl +Idosulfron methyl sodium | Pyroxulam | Twice hand weeding | Untreated weedy check |
|-----------|--------------------------------|--------------------------------------------|-----------|-------------------|----------------------|
|           | Weed count before application | Weed count after application | Efficacy (%) | Weed count before application | Weed count after application | Efficacy (%) | Weed count before 1st hand weeding | Weed count after 2nd hand weeding | Efficacy (%) | Weed count 1st | Weed count 2nd | Efficacy (%) |
| Bkelji    | Snowdenia polystachya         | 80                          | 0        | 100               | 40                          | 10        | 75        | 120                          | 0        | 100        | 160                          | 160        | 0          |
|           | Avena fatua                   | 68                          | 9        | 87                | 56                          | 6         | 89        | 42                          | 0        | 100        | 420                          | 430        | -2.3       |
|           | Bromus pectinatus             | 3400                        | 510      | 85                | 2180                        | 0         | 100       | 1740                        | 0        | 100        | 4200                         | 4300       | -2.3       |
|           | Phalaris paradoxa             | 25                          | 0        | 100               | 260                         | 0         | 100       | 100                         | 0        | 100        | 300                          | 340        | -11.7      |
|           | Gallium spurium               | 58                          | 0        | 100               | 43                          | 5         | 88        | 5                           | 0        | 100        | 3                            | 4          | -25        |
|           | Polygonum nepalense           | 117                         | 0        | 100               | 55                          | 0         | 100       | 50                          | 4        | 92         | 46                            | 47         | -4.2       |
|           | Gizotia scabra                | 17                          | 0        | 100               | 23                          | 0         | 100       | 15                          | 0        | 100        | 16                            | 18         | 0          |
|           | Galinsoga parviflora          | 0                           | 0        | -                 | 0                           | 0         | -         | 68                          | 3        | 95         | 55                            | 56         | 0          |
| Lole      | Snowdenia polystachya         | 1260                        | 0        | 100               | 860                         | 207       | 76        | 1140                        | 0        | 100        | 1420                         | 1460       | -2.7       |
|           | Avena fatua                   | 46                          | 6        | 87.5              | 32                          | 4         | 87.5      | 72                          | 0        | 100        | 0                             | 0          | 0          |
|           | Bromus pectinatus             | 1720                        | 256      | 85                | 1820                        | 0         | 100       | 1220                        | 0        | 100        | 2080                         | 2140       | -2.8       |
|           | Phalaris paradoxa             | 17                          | 0        | 100               | 21                          | 0         | 100       | 30                          | 0        | 100        | 0                             | 0          | 0          |
|           | Gallium spurium               | 94                          | 5        | 95                | 102                         | 14        | 86        | 19                          | 2        | 89         | 5                             | 6          | -16.6      |
|           | Polygonum nepalense           | 55                          | 0        | 100               | 30                          | 0         | 100       | 62                          | 3        | 95         | 50                            | 54         | -7.4       |
|           | Gizotia scabra                | 5                           | 1        | 80                | 9                            | 0         | 100       | 11                          | 0        | 100        | 15                            | 15         | 0          |
|           | Galinsoga parviflora          | 16                          | 1        | 94                | 28                           | 0         | 100       | 23                          | 0        | 100        | 68                            | 68         | 0          |

Efficacy measured on quadrats of 1 m by 1 m
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(2007) reported that Propoxycarbozone-sodium (Attribut 70WG) was effective against Bromus pectinatus and gave satisfactory suppression of Snowdenia polystachya across locations of the experimental sites. On the other hand, Shambel et al. (2000) reported that the herbicides sulfofurox and ethiozin, exhibited significant potential to control problematic grass weeds, including Brome grass in the wheat growing areas of Ethiopia. Similarly, both herbicides and two hand weedings controlled Gallium spurium, Gizotia scabra, Galinsoga parviflora and Polygonum nepalense at 80-100% efficacy level (Table 1). The negative values in the efficacy column of the untreated weedy check is resulted from the increasing late emergence of the weeds after the second weed count.

Mesosulfuron methyl +Idosulfuron methyl sodium is best recommended in areas where Snowdenia polystachya, Avena fatua, Phalaris paradoxa and Setaria pumila; and broad leaf weeds like Galinsoga parviflora, Gallium spuriurn, Gizotia scabra and Polygonum nepalense are problematic. For areas where Bromus pectinatus, Phalaris paradoxa, Setaria pumila, Lolium temulentum and broad leaf weeds like Polygonum nepalense, Galinsoga parviflora, Gizotia scabra are dominant weed problems, it is better to use Pyroxsulam.

**Yield and yield components.** Grain yield of wheat showed significant (P<0.05) differences due to Mesosulfuron methyl +Idosulfuron methyl sodium, Pyroxsulam and two hand weeding (Table 2). The highest grain yield was recorded in Mesosulfuron methyl +Idosulfuron methyl sodium; followed by Pyroxsulam and two hand weedings. The lowest grain yield was recorded in weedy check treatment.

The combined analysis over locations was not significant for plant height, spike length, TKW and HLW, but significant for weed dry weight, crop biomass and grain yield compared to the weedy check (Table 2). Yield wise, both Mesosulfuron methyl +Idosulfuron methyl sodium, Pyroxsulam and the two hand weedings outperformed the weedy check by 63, 58 and 53%, respectively. Mesosulfuron methyl +Idosulfuron methyl sodium had a yield advantage

| Treatment | Plant height (cm) | Spike length (cm) | Number of tillers/plant | TKW (g) | HLW (g) | Crop BM (kg ha⁻¹) | GY (kg ha⁻¹) | Weed biomass (kg ha⁻¹) |
|-----------|------------------|------------------|-------------------------|--------|--------|-------------------|------------|-----------------------|
| Pyroxsulam | 96.0 | 7.4 | 3.4 | 47.65 | 73.7 | 10750 | 4567b | 709 |
| Mesosulfuron methyl +Idosulfuron meth | 98.0 | 8.0 | 3.9 | 48.55 | 74.2 | 12808 | 4978 | 317 |
| Two hand weeding | 98.5 | 7.7 | 3.35 | 46.75 | 67.9 | 9792 | 4079 | 284 |
| Weedy check | 101.0 | 7.0 | 2.85 | 46.85 | 75.8 | 7467 | 1895 | 1492 |
| Mean | 98.4 | 7.5 | 3.35 | 46.88 | 73.6 | 8792 | 4079 | 284 |
| LSD (%) | 5.57 | 14.78 | 16.38 | 1.09 | 0.03 | 37.2 | 3.7 | 2.7 |

GY = Grain yield, TKW = Thousand kernel weight, HLW = Hector liter weight, CBM = Crop Biomass yield, NS = statistically non-significant
over Pyroxsulam, the two hand weedings and the weedy check (Table 2).

Dry weed mass showed significant difference (P<0.05) due to Mesosulfron methyl + Idosulfuron methyl sodium, Pyroxsulam and the two hand weedings. The lowest dry weed mass was recorded in Mesosulfron methyl + Idosulfuron methyl sodium treated plot; followed by two hand weedings and Pyroxsulam herbicide. The highest dry weed mass was recorded in untreated weedy checks (Table 2).

Economic analysis. Yield and economic data were collected to compare the economic advantage of each herbicide in different treatments. Accordingly, cost of Pyroxsulam was US$125 litre\(^{-1}\) and the cost of Mesosulfron methyl + Idosulfuron methyl sodium was US$50 litre\(^{-1}\) in 2012/13.

Labour costs for two hand weedings were determined by man-days and it was US$ 156.25 ha\(^{-1}\). Harvesting and threshing was done manually at 20 and 30 man days per hectare, respectively, with one daily labourer cost of US$1,875, and accordingly the cost for daily labourer for harvesting and threshing of wheat for Pyroxsulam, Mesosulfron methyl + Idosulfuron methyl sodium, two hand weeding and weedy check treatments was US$93.75, 93.75, 93.75 and 65.5 ha\(^{-1}\), respectively. The average grain price of wheat was US$37.5 per 100 kg in 2012/13 season. Labour cost for three times plowing was uniform for each treatment and cost US$140.5 ha\(^{-1}\).

### TABLE 3. Partial budget analysis for weed control with herbicides and two times hand weeding at three locations in Arsi Zone in Ethiopia

| List of different costs | Treatments                                                                 |
|-------------------------|---------------------------------------------------------------------------|
|                         | Pyroxsulam | Mesosulfron methyl + Idosulfuron methyl sodium | Two hand weeding | Weedy check |
| Adjusted mean yield (kg ha\(^{-1}\)) | 4110.3     | 4665.6                          | 3671.1            | 1705.5     |
| Gross field benefit (US$) | 1541.4     | 1746                            | 1376.7            | 639.6      |
| Cost of herbicide (US$) | 62.5        | 50                              | -                 | -          |
| herbicide application cost and rent for knapsack sprayer (US$) | 5.94        | 5.94                            | -                 | -          |
| Labor cost (US$) | -           | -                               | 156.25            | -          |
| Harvesting cost (US$) | 37.5        | 37.5                            | 37.5              | 28         |
| Threshing cost (US$) | 56.25       | 56.25                           | 56.25             | 37.5       |
| Total variable cost (US$) | 162.19     | 149.69                          | 250               | 65.5       |
| Net field benefit (US$) | 1379.21    | 1596.31                         | 1126.7            | 574.1      |

### TABLE 4. Marginal rate of return analysis for weed control with herbicides and two times hand weeding at three locations in Arsi Zone in Ethiopia

| Treatments                                                                 | Rate (l ha\(^{-1}\)) | Net field benefit (US$) | Total variable costs (US$) | MRR | MRR a |
|---------------------------------------------------------------------------|----------------------|-------------------------|-----------------------------|-----|-------|
| Weedy check                                                               | -                    | 574.1                   | 65.5                        |     |       |
| Pyroxsulam                                                                | 0.5                  | 1379.21                 | 162.19                      | 833 | 726   |
| Mesosulfron methyl + Idosulfuron methyl sodium                             | 1.0                  | 1596.31                 | 149.69                      | 1737| 1464  |
| Two hand weeding                                                          | -                    | 1126.7                  | 250                         | D   | D     |

* MRR calculated for cost of herbicides increased by 20%. D = treatments with MRR<50% considered as dominated.
rent for knapsack sprayer for herbicide application was US$5.94 ha⁻¹. The cost for land preparation and inputs (seed and fertilisers) were uniform for all treatments. To minimise unnecessary exaggerations of grain yield, productivity of the location mean grain yield obtained was adjusted by 10%.

Partial budget analysis indicated that application of Mesosulfuron methyl + Idosulfuron methyl sodium had the highest net field benefits (Table 3). Similarly, the marginal rate of return (MRR) analysis revealed that Mesosulfuron methyl + Idosulfuron methyl sodium was more profitable for farmers, and resulted in a MRR of 1737% (Table 4). In the sensitivity analysis (~MRR), Mesosulfuron methyl + Idosulfuron methyl sodium remained the most profitable weed treatment, even when the cost of herbicide was increased by 20%.

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