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# Saflufenacil: A new group of chemical herbicide for effective weed management in maize

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**Abstract**
A field experiment was conducted at Main Agricultural Research Station (MARS), College of Agriculture, Dharwad where six herbicides namely Glyphosate, Paraquat, Glufosinate ammonium, Saflufenacil, Halosulfuron and Imazethapyr were tried as a post emergence in addition to pre-emergence application of Atrazine. Totally nine treatments were tested using Randomized Block Design having three replications with two control (Weedy check and weed free check) and one standard RPP check. At all the growth stages weed free check was recorded higher weed control efficiency (WCE) than rest of the weed control methods. However after application of post emergence herbicides Atrazine @ 1 kg $ha^{-1}$ fb Glyphosate @ 2.5 kg $ha^{-1}$ was recorded with WCE of 92.12 percent next to weed free check. Weed free check was recorded significantly higher grain yield (84.59 q $ha^{-1}$), stover yield (114.10 q $ha^{-1}$) and harvest efficiency (42.57 %) which was followed by Atrazine @ 1 kg $ha^{-1}$ fb Saflufenacil @ 75 g $ha^{-1}$. Weed free check was recorded significantly higher gross return (₹ 98206 $ha^{-1}$), whereas Atrazine @ 1 kg $ha^{-1}$ fb Saflufenacil @ 75 g $ha^{-1}$ was recorded significantly higher net return (₹ 64405 $ha^{-1}$) and B:C ratio(3.14).

**Keywords:** Herbicides, Saflufenacil, maize, weed control efficiency, economics

## 1. Introduction
Maize (*Zea mays*), is the third most important cereal crop in the world after wheat and rice. In India, it is cultivated over an area of 9.43 m ha with a production of 24.26 m tonnes and the productivity is 2583 kg $ha^{-1}$ [1]. Maize has attained a commercial crop status due to its ease of cultivation, tolerance towards pest and diseases, high yield and better market price. It is adaptable to wide range of soil and climatic conditions, still there is a lot of scope to increase the present maize yields. The yields can be increased with many agronomic manipulations. Management of weeds is considered to be an important factor for achieving higher productivity as weed problem is more severe during continuous rains in early stages of maize growth which cannot be controlled by traditional and cultural practices alone due to too much wetness.

Weed infestation is one of the major constraints for low yield of maize as weeds compete with crop plants for essential inputs. Weed depletes 30-40 per cent of applied nutrients from the soil. The quantities of growth factors used by weeds are thus unavailable to the crop. Sequential use of pre and post emergent herbicides at temporal variation may help in avoiding the problem of weeds throughout the maize growth stages.

In order to control the weeds for longer period of the crop growth, there is a need for application of pre and post-emergence herbicides on sequential basis for the management of weeds. The current study was taken up with the objectives to find out Weed Control Efficiency, yield and economics of maize crop as influenced by application of pre and post emergence (non selective herbicides) herbicides in sequence.

## 2. Materials and methods
The experiment was conducted at Main Agricultural Research Station (MARS), College of Agriculture, Dharwad which is situated at $15^0$ 29' N latitude, $74^0$59' E longitudes and at an altitude of 689 m above mean sea level and it comes under Northern Transition Zone (Zone-8) of Karnataka. Six herbicides namely Glyphosate, Paraquat, Glufosinate ammonium, Saflufenacil, Halosulfuron and Imazethapyr were tried as a post emergence in addition to pre-

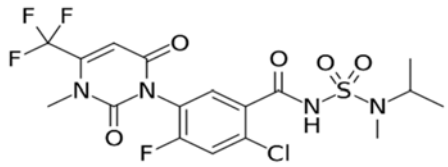
emergence application of Atrazine. Totally nine treatments were tested using Randomized Block Design having three replications with two control (Weedy check and weed free check) and one standard RPP check. During the experimental year (2014), rainfall of 962.20 mm was received which was 250.76 mm more than the normal.

**2.1 Saflufenacil**

Chemical name: 2-Chloro-5-[3, 6-dihydro-3-methyl-2, 6-dioxo-4- (trifluoromethyl) -1 (2*H*) -pyrimidinyl]-4-fluoro-*N*-[[methyl (1-methylethyl) amino]sulfonyl]benzamide

Trade name: Kixor Purity: 70%

Formulation: Wettable granules (WG)



**2.2 Uses:** It is post-emergence, non-selective, broad spectrum herbicide. It kills almost all the annuals, biennials and perennial weeds. It can even kill shrubs and trees. It has proven safe and effective on wheat, barley, oats, corn, cotton, dry beans (harvest aid/desiccant), English peas, grain sorghum, pulses, rice, legumes, soybeans and sunflowers (harvest aid/desiccant) and non-crop land uses.

**2.3 Mode of action:** Kixor herbicide is a potent inhibitor of chlorophyll biosynthesis, resulting in a rapid buildup of reactive oxygen species and lipid peroxidation of the cellular membranes. This drives a rapid loss of membrane integrity, leading to cellular leakage and rapid weed death. Kixor herbicide is readily absorbed by plant roots, shoots and leaves. Once absorbed, it is predominantly translocated via the xylem, with some movement in the phloem. It is a protoporphyrinogen oxidase (PPO) inhibitor (photodynamic toxicant, protoporphyrin IX accumulates in cells due to its inhibition).

**2.4 Observations on weed flora:** The important weed flora present in the experimental plot during the period of experimentation was recorded. In the experiment site, the weed infestation was predominantly consisted of grassy weeds, broad leaved weeds and sedges.

**2.5 Weed control efficiency (%)**

Weed control efficiency (WCE) denotes the magnitude of weed reduction due to the weed control treatments. The weed control efficiency was calculated by using the formula given by Misra and Tosh [8].

$$WCE\ (\%) = \frac{\text{Dry weight of weeds in Weedy check (g)} - \text{Dry weight of weeds in treatment plot (g)}}{\text{Dry weight of weeds in weedy check (g)}} \times 100$$

**2.6 Grain yield (q ha$^{-1}$)**

The cobs from the net plot were harvested at physiological maturity and they were dehusked. The dehusked cobs were air-dried and grains were separated from the cob by shelling and weighed the shelled grains after complete drying and taken as grain yield per plot. The grain yield was expressed in q ha$^{-1}$.

**2.7 Stover yield (q ha$^{-1}$)**

Stover yield was recorded after complete sun drying of stalks from each net plot and expressed in q ha$^{-1}$.

**2.8 Harvest index (%)**

Harvest index was defined as the ratio of economic yield to biological yield and expressed in per cent. Harvest efficiency was estimated as per the formula suggested by Donald [4].

$$HI\ (\%) = \frac{\text{Economic yield (q ha}^{-1})}{\text{Biological yield (q ha}^{-1})} \times 100$$

**2.9 Economics**

The prices of the inputs that were prevailing at the time of their use and market price of crop commodities were taken to work out the cost of cultivation and net returns. Benefit: cost ratio (B:C) was worked out by using the formula:

$$\text{Benefit: Cost ratio} = \frac{\text{Gross returns (₹ ha}^{-1})}{\text{Total cost of cultivation (₹ ha}^{-1})}$$

**3. Results and discussions**

**3.1 Weed Control Efficiency**

Weed control efficiency (WCE) differed significantly with different weed control methods at various crop growth stages (Table 1).

In weed control efficiency (WCE), total weed dry weight was taken into account which consists of different weed species which will be varying in their proportions. As such it will not reveal the individual weed species effect. WCE of treatment normally decreases over time or as the date of observation advances. Performance of crop is directly proportional to the weed control efficiency and inversely proportional to the weed index. In the present study, at 20, 40 and 60 DAS and also at harvest, $T_8$ (weed free check) was recorded higher WCE than rest of the weed control methods. There was no significant differences among herbicide treatments before application of post emergence herbicides. After pre emergence application of Atrazine, the weed control efficiency in each herbicides treatment did not varied significantly as commom herbicide was used in these treatments. But at 60 DAS, $T_8$ (weed free check) was recorded with higher WCE (97.26%) as compared to other treatments. The next best treatments were $T_1$ (Atrazine @ 1 kg ha$^{-1}$ fb Glyphosate @ 2.5 kg ha$^{-1}$) (92.12%), $T_3$ (Atrazine @ 1 kg ha$^{-1}$ fb Glufosinate ammonium @ 0.375 kg ha$^{-1}$) (91.73%), $T_4$ (Atrazine @ 1 kg ha$^{-1}$ fb Saflufenacil @ 75 g ha$^{-1}$) (90.04%) and $T_2$ (Atrazine @ 1 kg ha$^{-1}$ fb Paraquat @ 1 kg ha$^{-1}$) (89.14%) which were found on par with each other. It was due to lower weed population and total dry weight of weeds in these treatments due to better control of weeds following exposure to post emergent treatment [5, 12].

**3.2 Yield and Yield Components**

Yield of maize varied significantly among various weed control treatments (Table 2). Significantly higher grain yield (84.59 q ha$^{-1}$) was observed in $T_8$ (weed free check) which was 87.68 per cent higher than weedy check (45.07 q ha$^{-1}$) followed by $T_4$ (Atrazine @ 1 kg ha$^{-1}$ fb Saflufenacil @ 75 g ha$^{-1}$) (81.38 q ha$^{-1}$ which was 80.56 per cent higher than the weedy check). The next best treatment was $T_2$ (Atrazine @ 1 kg ha$^{-1}$ fb Paraquat @ 1 kg ha$^{-1}$) which was recorded with grain yield of 70.56 q ha$^{-1}$ (56.55 per cent more than weedy

check). In case of cob length, $T_8$ (weed free check), $T_4$ (Atrazine @ 1 kg ha$^{-1}$ fb Saflufenacil @ 75 g ha$^{-1}$) and $T_2$ (Atrazine @ 1 kg ha$^{-1}$ fb Paraquat @ 1 kg ha$^{-1}$) were recorded with 22.26, 18.61 and 14.74 per cent higher cob length over weedy check (13.97 cm) respectively. Yield is the net result of various interactions *i.e.* soil characters, weather parameters, crop weed competition and various metabolic and biochemical interactions taking place throughout the plant growth. Maize grain yield is also influenced by dry matter accumulation in different parts especially in reproductive part and yield components. Significantly higher yield obtained with the herbicides treatments was due to positive association between yield attributing characters *viz.,* cob length (cm), cob girth (cm), test weight (g), grain weight plant$^{-1}$ (g), shelling per cent and harvest efficiency as less weed competition and lesser phytotoxicity injury as well as better growth characteristics. Similar kind of results are also reported in case of vegetable cow pea [14] and in case of summer green gram [2]. Similar trends were also followed in case of yield attributing characters *viz.,* cob length (cm), cob girth (cm), test weight (g), grain weight plant$^{-1}$ (g), shelling per cent and harvest efficiency. Although highest WCE was observed in Glyphosate and Paraquat, Saflufenacil ($T_4$) recorded significantly higher yield due to less phytotoxic injury in this herbicide [3, 10 and 13]. In $T_1$ and $T_2$, more phytotoxicity injuries were observed and plants didi not recovered in these treatments, but in case of Saflufenacil plants recovered afterwards.

Significant differences in stover yield (q ha$^{-1}$) was recorded with respect to different weed control treatments (Table 3). $T_8$ (weed free check) recorded significantly higher stover yield (114.10 q ha$^{-1}$) which was 71.83 per cent higher over weedy check (66.40 q ha$^{-1}$) and it was on par with $T_4$ (Atrazine @ 1 kg ha$^{-1}$ fb Saflufenacil @ 75 g ha$^{-1}$) having stover yield 109.80 q ha$^{-1}$ (65.36 per cent higher over weedy check). The next best treatment was $T_2$ (Atrazine @ 1 kg ha$^{-1}$ fb Paraquat @ 1 kg ha$^{-1}$) which recorded stover yield of 102.10 q ha$^{-1}$ (53.76 per cent higher over weedy check). Higher stover yield may be attributed to higher dry matter production and its accumulation in leaves, stem, reproductive parts and also other growth attributes such as plant height, number of leaves, leaf area and leaf area efficiency [3, 7].

### 3.3 Economics

The economics in terms of net returns has a greater impact on the practical utility and acceptance of the technology. Gross returns, net returns and B:C ratio was differed significantly due to different weed control treatments. The results are presented in Table 3.

The highest cost of cultivation (₹ 35469 ha$^{-1}$) was recorded with $T_8$ (weed free check) which was due to more manual labour engagement for continuous weeding to keep the plot weed free. Among the herbicide treatments $T_5$ (Atrazine @ 1 kg ha$^{-1}$ fb Halosulfuron @ 90 g ha$^{-1}$) recorded higher cost of cultivation (₹ 34781 ha$^{-1}$) due to higher cost of halosulfuron. Significantly higher gross return (₹ 98206 ha$^{-1}$) was observed in $T_8$ (weed free check) followed by $T_4$ (Atrazine @ 1 kg ha$^{-1}$ fb Saflufenacil @ 75 g ha$^{-1}$) (₹ 94474 ha$^{-1}$). The next best treatment was $T_2$ (Atrazine @ 1 kg ha$^{-1}$ fb Paraquat @ 1 kg ha$^{-1}$) which recorded gross returns of ₹ 82330 ha$^{-1}$. $T_4$ (Atrazine @ 1 kg ha$^{-1}$ fb Saflufenacil @ 75 kg ha$^{-1}$) recorded significantly higher net return (₹ 64405 ha$^{-1}$) which was on par with $T_8$ (weed free check) (₹ 62737 ha$^{-1}$). The next best treatment was $T_2$ (Atrazine @ 1 kg ha$^{-1}$ fb Paraquat @ 1 kg ha$^{-1}$) which recorded net return of ₹ 51664 ha$^{-1}$. Significantly higher B:C ratio (3.14) was observed with $T_4$ (Atrazine @ 1 kg ha$^{-1}$ fb Saflufenacil 75 g ha$^{-1}$) followed by $T_8$ (weed free check) (2.77). $T_2$ (Atrazine @ 1 kg ha$^{-1}$ fb Paraquat @ 1 kg ha$^{-1}$) which recorded B:C ratio of 2.68 was the next best treatment.

The cost of cultivation in the weed free treatment is higher than other herbicide treatments due to consumption of high manual labour for continuous weeding which contributed higher cost to this treatment as labour cost is high than the cost of herbicide. The gross return contributed directly through the grain yield. So Weed free followed by Saflufenacil treatment showed higher gross return. But the higher net returns in Saflufenacil treatment could be attributed to higher grain yield, stover yield and lower cost of cultivation. So from the economical point of view the treatment having higher net return is useful for the farmers. The lower B:C ratio was recorded with weedy check which was due to less gross returns as a result of lower yield of maize [5, 9].

It is concluded that among the herbicides tried, Atrazine @ 1 kg ha$^{-1}$ fb Saflufenacil @ 75 g ha$^{-1}$ as directed spray at 45 days after sowing ($T_4$) is found to be the best weed control method for rainfed maize because it is recorded higher grain yield, net returns, B:C ratio as well as WCE as compared to other herbicides treatments.

**Table 1:** Weed Control efficiency (%) as influenced by weed control methods in maize

| Treatments | Weed control efficiency (%) | | | |
|---|---|---|---|---|
| | 20 DAS | 40 DAS | 60 DAS | Harvest |
| $T_1$ - Atrazine @ 1 kg ha$^{-1}$ fb Glyphosate @ 2.5 kg ha$^{-1}$ (Directed spray) | 72.40 | 43.71 | 92.12 | 85.56 |
| $T_2$ - Atrazine @ 1 kg ha$^{-1}$ fb Paraquat @ 1 kg ha$^{-1}$ (Directed spray) | 71.27 | 43.68 | 89.14 | 71.89 |
| $T_3$ - Atrazine @ 1 kg ha$^{-1}$ fb Glufosinate ammonium @ 0.375 kg ha$^{-1}$ (Directed spray) | 77.36 | 48.18 | 91.73 | 84.84 |
| $T_4$ - Atrazine @ 1 kg ha$^{-1}$ fb Saflufenacil @ 75 g ha$^{-1}$ (Directed spray) | 75.19 | 50.57 | 90.40 | 77.13 |
| $T_5$ - Atrazine @ 1 kg ha$^{-1}$ fb Halosulfuron @ 90 g ha$^{-1}$ (Directed spray) | 73.91 | 42.61 | 81.09 | 69.98 |
| $T_6$ - Atrazine @ 1 kg ha$^{-1}$ fb Imazethapyr @ 75 g ha$^{-1}$ (Directed spray) | 70.37 | 42.75 | 75.56 | 70.43 |
| $T_7$ - Atrazine @ 1 kg ha$^{-1}$ + 2 IC + 1 HW ( RPP standard check) | 76.81 | 81.50 | 86.62 | 56.46 |
| $T_8$ - Weed free check | 91.89 | 90.19 | 97.26 | 91.55 |
| $T_9$ - Weedy check | - | - | - | - |
| S. Em± | 4.96 | 2.73 | 1.54 | 2.42 |
| CD (0.05) | 14.87 | 8.17 | 4.63 | 7.27 |

IC: Inter cultivation HW: Hand Weeding fb: followed by

Note: All the above mentioned post-emergent ($T_1$-$T_6$) herbicides sprayed as directed spray at 45 DAS

**Table 2:** Grain yield (q ha$^{-1}$), Stover yield (qha$^{-1}$) and harvest index (%) as influenced by weed control methods in maize

| Treatments | Grain yield (q ha$^{-1}$) | Stover yield (q ha$^{-1}$) | Harvest index (%) |
|---|---|---|---|
| $T_1$ - Atrazine @ 1 kg ha$^{-1}$ fb Glyphosate @ 2.5 kg ha$^{-1}$ (Directed spray) | 59.11 | 83.00 | 41.63 |
| $T_2$ - Atrazine @ 1 kg ha$^{-1}$ fb Paraquat @ 1 kg ha$^{-1}$ (Directed spray) | 70.56 | 102.10 | 40.86 |
| $T_3$ - Atrazine @ 1 kg ha$^{-1}$ fb Glufosinate ammonium @ 0.375 kg ha$^{-1}$ (Directed spray) | 65.83 | 95.30 | 40.87 |
| $T_4$ - Atrazine @ 1 kg ha$^{-1}$ fb Saflufenacil @ 75 g ha$^{-1}$ (Directed spray) | 81.38 | 109.80 | 42.56 |
| $T_5$ - Atrazine @ 1 kg ha$^{-1}$ fb Halosulfuron @ 90 g ha$^{-1}$ (Directed spray) | 67.83 | 98.57 | 40.78 |
| $T_6$ - Atrazine @ 1 kg ha$^{-1}$ fb Imazethapyr @ 75 g ha$^{-1}$ (Directed spray) | 62.67 | 91.30 | 40.70 |
| $T_7$ - Atrazine @ 1 kg ha$^{-1}$ + 2 IC + 1 HW ( RPP standard check) | 68.17 | 94.67 | 41.86 |
| $T_8$ - Weed free check | 84.59 | 114.10 | 42.57 |
| $T_9$ - Weedy check | 45.07 | 66.40 | 40.45 |
| S. Em± | 0.68 | 1.63 | 0.34 |
| CD (0.05) | 2.05 | 4.87 | 1.02 |

IC: Inter cultivation HW: Hand Weeding fb: followed by
Note: All the above mentioned post-emergent ($T_1$-$T_6$) herbicides sprayed as directed spray at 45 DAS

**Table 3:** Cost of cultivation (₹ ha$^{-1}$), gross returns (₹ ha$^{-1}$), net returns (₹ ha$^{-1}$) and B:C ratio as influenced by weed control methods in maize

| Treatments | Cost of cultivation (₹ ha$^{-1}$) | Gross Return (₹ ha$^{-1}$) | Net Return (₹ ha$^{-1}$) | B : C ratio |
|---|---|---|---|---|
| $T_1$ - Atrazine @ 1 kg ha$^{-1}$ fb Glyphosate @ 2.5 kg ha$^{-1}$ (Directed spray) | 30971 | 68815 | 37844 | 2.22 |
| $T_2$ - Atrazine @ 1 kg ha$^{-1}$ fb Paraquat @ 1 kg ha$^{-1}$ (Directed spray) | 30666 | 82330 | 51664 | 2.68 |
| $T_3$ - Atrazine @ 1 kg ha$^{-1}$ fb Glufosinate ammonium @ 0.375 kg ha$^{-1}$ (Directed spray) | 30431 | 76818 | 46387 | 2.52 |
| $T_4$ - Atrazine @ 1 kg ha$^{-1}$ fb Saflufenacil @ 75 g ha$^{-1}$ (Directed spray) | 30069 | 94474 | 64405 | 3.14 |
| $T_5$ - Atrazine @ 1 kg ha$^{-1}$ fb Halosulfuron @ 90 g ha$^{-1}$ (Directed spray) | 34781 | 79170 | 44389 | 2.28 |
| $T_6$ - Atrazine @ 1 kg ha$^{-1}$ fb Imazethapyr @ 75 g ha$^{-1}$ (Directed spray) | 30371 | 73158 | 42787 | 2.41 |
| $T_7$ - Atrazine @ 1 kg ha$^{-1}$ + 2 IC + 1 HW ( RPP standard check) | 33045 | 79303 | 46258 | 2.40 |
| $T_8$ - Weed free check | 35469 | 98206 | 62737 | 2.77 |
| $T_9$ - Weedy check | 27469 | 52659 | 25190 | 1.92 |
| S. Em ± | - | 796 | 796 | 0.03 |
| CD (0.05) | - | 2389 | 2389 | 0.08 |

IC: Inter cultivation HW: Hand Weeding fb: followed by
Note: All the above mentioned post-emergent ($T_1$-$T_6$) herbicides sprayed as directed spray at 45 DAS

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