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# Allelopathic Crop Water Extracts Reduce the Herbicide Dose for Weed Control in Cotton (*Gossypium hirsutum*)

JAVAID IQBAL[1], ZAHID ATA CHEEMA† AND M. NAEEM MUSHTAQ†
*College of Agriculture, Dera Ghazi Khan, Pakistan*
*†Weed Science-Allelopathy Lab. Department of Agronomy, University of Agriculture, Faisalabad, Pakistan*
[1]Corresponding author's e-mail: javaidleghari@hotmail.com

## ABSTRACT

Crop allelopathy can be manipulated for achieving sustainable weed management. Less inhibition of weeds is generally achieved through allelopathic interactions than the standard weed control limits. Combination of allelopathic crop water extracts with lower rate of herbicides may provide lower desired weed control levels there by reducing herbicide usage. Two field studies were conducted utilizing water extracts of allelopathic crops sorghum (*Sorghum bicolor* L.), sunflower (*Helianthus annuus* L.) and brassica (*Brassica napus* L.) with reduced glyphosate dosage for controlling purple nutsedge in cotton. In first experiment sorghum and brassica water extracts were tank mixed (at 15 & 18 L ha$^{-1}$) in different combinations with reduced rate of glyphosate by 767 and 575 g a.e. ha$^{-1}$ and sprayed as directed post emergence at 21 days after sowing (DAS). In second experiment sorghum and sunflower water extracts were mixed with glyphosate at same dose as in experiment 1. Purple nutsedge density and dry weight were suppressed by 78% to 95% and 83% to 95% respectively, when different crop water extracts were used in combination with reduced rate of glyphosate. Seed cotton yield was improved from 15-21% in sorgaab and brassica water extract combinations with reduced rates of glyphosate (67-75%). However, the yield improvement in the combination of sorgaab and sunflower water extracts was comparatively less (13-19%) with similar reduction in herbicides dose.

**Key Words:** Crop water extracts; Sunflower; Sorgaab; Brassica; Glyphostae; Purple nutsedge

## INTRODUCTION

Purple nutsedge was ranked as the world's worst weed based on world wide distribution (considered weeds in at least 92 countries) and importance in many diverse crops (infesting at least 52 different crops; Holm *et al.,*1978; Rao, 2000). In corn, cotton, peanut, soybean, tobacco and vegetables, it is among the top five most troublesome weeds (Webster & MacDonald, 2001; Webster, 2005) and highly competitive especially under high soil nitrogen conditions (Morales-Payan *et al.,* 1998; Santos *et al*., 1998). It is a major pest in cotton under irrigated conditions. As a $C_4$ species, it is well adopted in hot and dry climates. Reproduction is largely or entirely by below ground production of vegetative tubers (Grantz & Shrestha, 2006).

In Pakistan it is among the most common weeds found throughout the Indus valley during summer season in major field crops such as cotton, sugarcane and maize. Purple nutsedge is highly competitive and causes seed cotton yield reduction by 62-85% as compared with no purple nutsedge control treatments (Bryson *et al*., 2003). It can harbor cotton pests and diseases, reduce irrigation efficiency (Rao, 2000). It is difficult to effectively control purple nutsedge through usual weed control methods because of its specific biological characteristics i.e., having different means of propagation (seeds rhizomes, tubers) with varying degree of dormancy (Charles, 1997). Usual weed control methods; manual or mechanical, kill only the top growth with little effect on tubers. Very few selective herbicides for purple nutsedge are available. Further more, chemical weed control involves safety risks and may enhance environmental pollution. The continuous use of herbicides may cause weed shift problem and weed resistance to herbicides (Zhang, 2003). Scientists worldwide are looking for alternative methods in weed management (Bhowmik, 2007). Allelopathy has been recognized as a chemical warfare among the plant species. Use of allelopathic potential in the service of weed managers is of recent discussion (Hassan & Khan, 2007). Moreover, the costs of using herbicides to control weeds are increasing and it is rapidly out of farmer's affordability. The chemical weed control is generally unsafe and increasingly causing risk concerns with human and environmental health (Duke *et al*., 2001). Therefore, alternatives for safe, cheap, yet effectively controlling purple nutsedge in cotton crops are urgently required in Pakistan.

The organic chemical compounds having herbicidal properties may be combined with allelopathic water extracts

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at lower doses (Cheema *et al.*, 2003 & 2005). This, on one side, may improve the efficacy of allelopathic extracts and on other side may provide the opportunities of reducing the herbicidal doses and hence the cost of weed control could be lowered, promoting sustainable environmental safety. Crop plants like sorghum (Cheema *et al*., 2002; Alsaadawi, 2007), sunflower (Batish *et al*., 2002) and brassica (Weston & Duke, 2003; Turk *et al*., 2003), have been reported to exhibit allelopathic effects on the associated weeds. The allelochemicals in these plants may be same or different, which might show synergistic or additive effects in combination (Duke & Laydon, 1993). Allelopathic crops may be used in different ways to influence weeds such as, surface mulch (Cheema *et al*., 2000), incorporation into the soil (Sati *et al*., 2004), spraying of water extracts (Cheema *et al*., 2002), rotation (Narwal, 2000), smothering (Singh *et al*., 2003) or mixed cropping and intercropping (Hatcher & Melander, 2003). Recently Iqbal and Cheema (2007) reported an effective control of purple nutsedge by utilizing natural plant extracts from various allelopathic crops (sorghum, sunflower & brassica) in the field. Their results showed that 12 and 15 L $ha^{-1}$ crop water extracts, mixed with reduced rate of glyphosate, decreased purple nutsedge density by 59 to 99% and dry weight by 66% to 99%, which was achieved by reducing glyphosate application rate by up to 67%.

The present studies were therefore, designed to investigate the possibilities of reduction of herbicide dose (up to 75%) using higher level crop water extracts (sorgaab, brassica & sunflower each at 15 and 18 L $ha^{-1}$) for getting effective purple nutsedge control in cotton.

## MATERIALS AND METHODS

Field experiments were conducted during, 2006 at farmer's field at Choti Zareen district Dera Ghazi Khan, (30.03°N, 70.38°E). Water extracts of Sorghum, sunflower and brassica were prepared by following the procedure developed by Cheema and Khaliq (2000). Experiments were laid out in RCBD (Randomised Complete Block Design) with four replications in plots measuring 8 m×3 m. Trials were conducted in field previously heavily infested with purple nutsedge. After preparation of field, 25 cm raised and 75 cm spaced ridges were made. Cotton cv. CIM-496 was sown on dry soil on 20th May, 2006 on both sides of the ridges maintaining the row to row distance of 75 cm. Immediate after the sowing, ridges were irrigated up to a level of 5 cm below the seed line so that only seepage of water can soak the seed and to avoid the soil crusting. Later on plant population was maintained by adjusting plant to plant distance at 30 cm. Fertilizer was applied at 115 kg N, 57 kg $P_2O_5$ $ha^{-1}$ as urea and triple super phosphate, respectively. In the first experiment combinations of sorgaab and brassica water extracts each @ 15 and 18 L $ha^{-1}$ were tank mixed with one third and one fourth of glyphosate dose (767 & 575 g a.e. $ha^{-1}$). Glyphosate (Round up 490 GL) @ 2.3 kg a.e. $ha^{-1}$ (recommended rate) and weedy check treatments were maintained for comparison. In the second experiment combinations of sorgaab and sunflower water extracts each @ 15 and 18 L $ha^{-1}$ were tank mixed with one third and one fourth of glyphosate dose (767 & 575 g a.e. $ha^{-1}$). Glyphosate (Round up 490 GL) @ 2.3 kg a.e. $ha^{-1}$ (recommended rate) and weedy check treatments were maintained for comparison. Herbicide and water extract combinations were sprayed as directed post-emergence at 21 DAS (days after sowing). Volume of the spray was calibrated to 300 L $ha^{-1}$ and treatments were applied with Knapsack hand sprayer fitted with flat fan nozzle. All Agronomic operations except those under study were kept normal and uniform for all treatments. Data on purple nutsedge density and biomass were recorded at 35 and 65 DAS from two randomly selected quadrates (50×50 cm) from each experimental plot. Purple nutsedge dry weight was recorded after oven drying at 80°C for 48 h. Data on cotton were recorded for cotton plant height (cm), monopodial branches per plant, sympodial branches per plant, number of bolls per plant, boll weight (g) and seed cotton yield (kg $ha^{-1}$) from each plot using standard sampling procedures. Statistical software package "MSTAT C" was used to analyze all the data (Anonymous, 1986). Least significance difference (LSD) test was applied at 5% level of significance to compare treatment means. Analysis of economic returns was accomplished by following the procedure laid down by Byerlee (1988). Variable costs ($ha^{-1}$) of purchased inputs, labor and machinery were determined by the market prices. Net benefits were calculated by subtracting the total variable cost from the gross benefits for each treatment.

## RESULTS

### Purple Nutsedge Growth

**Experiment 1.** Different combinations of sorgaab with brassica water extracts and reduced rates of glyphosate significantly inhibited the purple nutsedge population and dry matter production relative to control (Table I). Sorgaab with brassica each @ 18 L $ha^{-1}$ tank mixed with glyphosate @ 767 g a.e. $ha^{-1}$ (1/3rd of recommended) suppressed weed density by 89-95% and recorded at 35 and 65 DAS, respectively and was on par with the recommended dose of glyphosate i.e., 2.3 kg a.e. $ha^{-1}$ (94-97%). The combination of sorgaab and brassica each @ 18 L $ha^{-1}$ and 1/4th of the recommended dose of glyphosate also effectively suppressed purple nutsedge density. Almost similar results were observed for purple nutsedge dry weight at both intervals (35 & 65 DAS).

**Experiment 2.** Purple nutsedge density and dry weight were significantly inhibited by the use of sorgaab and sunflower extract combined with reduced herbicide (glyphosate) rates as compared to control (Table II). Although highest suppression was recorded for glyphosate recommended dose (93-96%) at both intervals yet it was

**Table I. Effect of sorgaab and brassica water extracts in combination with glyphosate on purple nutsedge density and dry weight**

| Treatments | | Purple nutsedge density (0.25 $m^{-2}$) | | Purple nutsedge dry weight (g 0.25 $m^{-2}$) | |
|---|---|---|---|---|---|
| Extract/herbicide (directed post-emergence 21 DAS) | Rate | 35 DAS | 65 DAS | 35 DAS | 65 DAS |
| Weedy check | | 117.75 a† (0) | 123.75 a† (0) | 40.11 a† (0) | 42.05 a† (0) |
| Sorgaab + BWE + glyphosate | Each 15 L+767 g a.e. $ha^{-1}$ | 21.75 bc (-81.53) | 13.25 bc (-89.29) | 6.24 b (-84.46) | 3.79 bc (-90.98) |
| Sorgaab + BWE + glyphosate | Each 18 L+767 g a.e. $ha^{-1}$ | 12.75 de (-89.17) | 6.5 de (-94.75) | 3.70 cd (-90.78) | 2.01 de (-95.21) |
| Sorgaab + BWE + glyphosate | Each 15 L+575 g a.e. $ha^{-1}$ | 25.5 b (-78.34) | 17 b (-86.26) | 6.70 b (-83.30) | 4.56 b (-89.16) |
| Sorgaab + BWE + glyphosate | Each 18 L+575 g a.e. $ha^{-1}$ | 17.5 cd (-85.14) | 9.5 cd (-92.32) | 4.90 bc (-87.80) | 2.79 cd (-93.37) |
| Glyphosate | 2.3 kg a.e. $ha^{-1}$ | 7.5 e (-93.63) | 4.25 e (-96.57) | 2.18 d (-94.57) | 1.30 e (-96.92) |
| LSD ($p<0.05$) | | 7.966 | 3.952 | 2.234 | 1.467 |

DAS= Days after sowing
†=Means not sharing a letter in common differ significantly at $p<0.05$
Figure in parenthesis show percent decrease over control
Sorgaab= Sorghum water extract; BWE= Brassica water extract

**Table II. Effect of sorgaab and sunflower water extracts in combination with glyphosate on purple nutsedge density and dry weight**

| Treatments | | Purple nutsedge density (0.25 $m^{-2}$) | | Purple nutsedge dry weight (g 0.25 $m^{-2}$) | |
|---|---|---|---|---|---|
| Extract/herbicide (directed post-emergence 21 DAS) | Rate | 35 DAS | 65 DAS | 35 DAS | 65 DAS |
| Weedy check | | 120.75 a† (0) | 125.75 a† (0) | 42.44 a† (0) | 43.81 a† (0) |
| Sorgaab + SFWE + glyphosate | Each 15 L+767 g a.e. $ha^{-1}$ | 18.00 c (-85.09) | 13.13 c (-89.56) | 5.97 c (-85.92) | 4.22 c (-90.37) |
| Sorgaab + SFWE + glyphosate | Each 18 L+767 g a.e. $ha^{-1}$ | 13.25 d (-89.03) | 8.75 cd (-93.04) | 4.37 d (-89.70) | 2.92 cd (-93.35) |
| Sorgaab + SFWE + glyphosate | Each 15 L+575 g a.e. $ha^{-1}$ | 27.25 b (-77.43) | 18.75 b (-85.09) | 9.00 b (-78.79) | 6.15 b (-85.96) |
| Sorgaab + SFWE + glyphosate | Each 18 L+575 g a.e. $ha^{-1}$ | 18.00 c (-85.09) | 9.75 cd (-92.25) | 6.03 c (-85.80) | 3.25 cd (-92.59) |
| Glyphosate | 2.3 kg a.e. $ha^{-1}$ | 8.00 e (-93.37) | 5.38 d (-95.73) | 2.67 e (-93.71) | 1.74 d (-96.03) |
| LSD ($p<0.05$) | | 4.65 | 5.244 | 1.373 | 1.848 |

DAS= Days after sowing
†=Means not sharing a letter in common differ significantly at $p<0.05$
Figure in parenthesis show percent decrease over control
Sorgaab= Sorghum water extract; SFWE= Sunflower water extract

**Table III. Effect of sorgaab and brassica water extracts in combination with glyphosate on growth, yield parameters and seed cotton yield**

| Treatments Extract/herbicide (directed post-emergence 21 DAS ) | Rate | Plant height (cm) | Monopodial branches per plant | Sympodial branches per plant | Number of Bolls per plant | Boll weight (g) | Seed Cotton Yield (kg $ha^{-1}$) |
|---|---|---|---|---|---|---|---|
| Weedy check | | 95.5 c† | 1.1 d† | 18.4 c† | 22.4 d† | 3.2 c† | 1786.11 c (0) |
| Sorgaab + BWE + glyphosate | Each 15 L+767 g a.e. $ha^{-1}$ | 133 ab | 1.4 bc | 26.3 ab | 32.4 b | 3.85 b | 2126.11 ab (19.04) |
| Sorgaab + BWE + glyphosate | Each 18 L+767 g a.e. $ha^{-1}$ | 137.5 a | 1.7 a | 28.1 a | 34.8 a | 4.3 a | 2167.78 a (21.37) |
| Sorgaab + BWE + glyphosate | Each 15 L+575 g a.e. $ha^{-1}$ | 129.5 b | 1.3 cd | 25.8 b | 29.8 c | 3.7 b | 2062.22 b (15.46) |
| Sorgaab + BWE + glyphosate | Each 18 L+575 g a.e. $ha^{-1}$ | 134 ab | 1.5 abc | 26.7 ab | 31.2 bc | 3.8 b | 2088.89 ab (16.95) |
| Glyphosate | 2.3 kg a.e. $ha^{-1}$ | 136 ab | 1.6 ab | 27.6 ab | 35.6 a | 4.2 a | 2175.00 a (21.77) |
| LSD ($p<0.05$) | | 7.446 | 0.282 | 1.936 | 2.2 | 0.2696 | 92.24 |

†=Means not sharing a letter in common differ significantly at $p<0.05$
Figure in parenthesis show percent increase over control
Sorgaab= Sorghum water extract; BWE= Brassica water extract

statistically similar to sorgaab and sunflower each @ 18 L $ha^{-1}$ combined with either 1/3rd (767 g a.e. $ha^{-1}$) at both intervals or 1/4th (575 g a.e. $ha^{-1}$) at 65 DAS. Minimum suppression was observed with sorgaab and sunflower each @ 15 L $ha^{-1}$ combined with 1/4th of recommended dose of glyphosate at both intervals (35 & 65 DAS). The trend of inhibition in dry weight of purple nutsedge was almost same as in case with population of the weed. Higher rate of crop water extracts (18 L $ha^{-1}$) suppressed equally the purple nutsedge density and dry weight with 1/4th of recommended glyphosate dose as with 1/3rd of glyphosate.

**Cotton Growth and Yield**

**Experiment 1.** All the combinations of sorgaab with brassica water extracts and reduced herbicide rates significantly improves plant height, sympodial branches, number of bolls per plant, boll weight and seed cotton yield as compared to control (Table III). The highest plants were observed for sorgaab with brassica each @ 18 L $ha^{-1}$+767 g a.e. $ha^{-1}$ and were on par with sorgaab+brassica each @ 15 L $ha^{-1}$+767 g a.e. $ha^{-1}$, sorgaab+brassica each @ 18 L $ha^{-1}$ +575 g a.e. $ha^{-1}$ and glyphosate at recommended dose. All most similar results were observed in case of monopodial

**Table IV. Effect of sorgaab and sunflower water extracts in combination with glyphosate on growth, yield parameters and seed cotton yield**

| Treatments (Extract/herbicide directed post-emergence 21 DAS ) | Rate | Plant height (cm) | Monopodial branches per plant | Sympodial branches per plant | Number of Bolls per plant | Boll weight (g) | Seed Cotton Yield (kg ha$^{-1}$) |
|---|---|---|---|---|---|---|---|
| Weedy check | | 98.00 e† | 1.0 c† | 18.1 d† | 23.0 d† | 3.3 d† | 1803.89 e (0) |
| Sorgaab + SFWE + glyphosate | Each 15 L+767 g a.e. ha$^{-1}$ | 135.50 ab | 1.3 ab | 26.2 bc | 33.6 b | 4.0 b | 2107.78 bc (16.85) |
| Sorgaab + SFWE + glyphosate | Each 18 L+767 g a.e. ha$^{-1}$ | 132.00 c | 1.5 a | 27.9 ab | 35.8 a | 4.3 a | 2153.89 a (19.40) |
| Sorgaab + SFWE + glyphosate | Each 15 L+575 g a.e. ha$^{-1}$ | 134.00 bc | 1.2 bc | 25.3 c | 32.2 c | 3.7 c | 2037.78 d (12.97) |
| Sorgaab + SFWE + glyphosate | Each 18 L+575 g a.e. ha$^{-1}$ | 128.50 d | 1.4 ab | 26.4 abc | 33.8 b | 3.9 bc | 2072.22 cd (14.88) |
| Glyphosate | 2.3 kg a.e. ha$^{-1}$ | 137.00 a | 1.5 a | 28.2 a | 36.2 a | 4.4 a | 2147.22 ab (19.03) |
| LSD (p<0.05) | | 2.099 | 0.286 | 1.858 | 1.34 | 0.2286 | 42.03 |

†=Means not sharing a letter in common differ significantly at p<0.05
Figure in parenthesis show percent increase over control
Sorgaab= Sorghum water extract; SFWE= Sunflower water extract

**Table V. Economic Analysis of cotton as influenced by sorgaab+brassica water extract combinations with reduced rates of glyphosate**

| Parameters | $T_1$ | $T_2$ | $T_3$ | $T_4$ | $T_5$ | $T_6$ | Remarks |
|---|---|---|---|---|---|---|---|
| Seed cotton yield (kg ha$^{-1}$) | 1786 | 2126 | 2168 | 2062 | 2089 | 2175 | kg ha$^{-1}$ |
| Adjusted seed cotton yield (kg ha$^{-1}$) | 1608 | 1914 | 1951 | 1856 | 1880 | 1958 | 10% less than actual yield |
| Gross benefit (Rs. ha$^{-1}$) | 44220 | 52635 | 53653 | 51040 | 51700 | 53845 | Rs. 1100/ 40 kg |
| Cost of herbicide | - | 782 | 782 | 587 | 587 | 2347 | Round up Rs. 500/L |
| Cost of water extracts preparation | - | 150 | 180 | 150 | 180 | - | Rs. 75/15 Lconc water extract preparation |
| Labor charges of spray | - | 150 | 150 | 150 | 150 | 150 | @ Rs. 150/man ha$^{-1}$ |
| Sprayer rent | - | 60 | 60 | 60 | 60 | 60 | Rs. 60 ha$^{-1}$ |
| Cost that vary | - | 1142 | 1172 | 947 | 977 | 2557 | Rs. ha$^{-1}$ |
| Net benefits | 44220 | 51493 | 52481 | 50093 | 50723 | 51288 | Rs. ha$^{-1}$ |
| | | 16.45 | 18.68 | 13.28 | 14.71 | 15.98 | % increase over control |

$T_1$: Control (Weedy check); $T_2$: Sorgaab+brassica each at 15 L ha$^{-1}$+glyphosate @ 767 g a.e. ha$^{-1}$; $T_3$: Sorgaab+brassica each at 18 L ha$^{-1}$+glyphosate @ 767 g a.e. ha$^{-1}$; $T_4$: Sorgaab+brassica each at 15 L ha$^{-1}$+glyphosate @ 575 g a.e. ha$^{-1}$; $T_5$: Sorgaab+brassica each at 18 L ha$^{-1}$+glyphosate @ 575 g a.e. ha$^{-1}$; $T_6$: Glyphosate at 2.3 kg a.e ha$^{-1}$ (label rate)

**Table VI. Dominance and marginal analysis of cotton as influenced by sorgaab+brassica water extract combinations with reduced rates of glyphosate**

| Treatments (directed post emergence 21 DAS) | Total cost that vary (Rs.) | Net benefits (Rs.) | Marginal costs (Rs.) | Marginal net benefits (Rs.) | Marginal rate of return (%) |
|---|---|---|---|---|---|
| Control (Weedy check) | 0 | 44220 | - | - | - |
| Sorgaab + brassica each at 15 L ha$^{-1}$ + glyphosate @ 575 g a.e. ha$^{-1}$ | 947 | 50093 | 947 | 5873 | 620.17 |
| Sorgaab + brassica each at 18 L ha$^{-1}$ + glyphosate @ 575 g a.e. ha$^{-1}$ | 977 | 50723 | 30 | 630 | 2100.00 |
| Sorgaab + brassica each at 15 L ha$^{-1}$ + glyphosate @ 767 g a.e. ha$^{-1}$ | 1142 | 51493 | 164 | 770 | 466.67 |
| Sorgaab + brassica each at 18 L ha$^{-1}$ + glyphosate @ 767 g a.e. ha$^{-1}$ | 1172 | 52481 | 30 | 988 | 3293.33 |
| Glyphosate at 2.3 kg a.e ha$^{-1}$ | 2557 | 51288 | 1385 | - | - |

D = Dominated treatment
DAS= Days after sowing
Rs. = Rupees

and sympodial branches per plant except in case of monopodial branches, the combination of sorgaab+brassica each @ 15 L ha$^{-1}$+575 g a.e. ha$^{-1}$ was similar to the weedy check. More number of bolls and heavier bolls were recorded with recommended dose of glyphosate (2.3 kg a.e. ha$^{-1}$) and were similar to sorgaab+brassica each @ 18 L ha$^{-1}$ +glyphosate 767 g a.e. ha$^{-1}$. Maximum seed cotton yield (22% increase over control) was recorded at recommended dose of glyphosate and was similar to sorgaab+brassica each @ 15 or 18 L ha$^{-1}$+glyphosate 767 g a.e. ha$^{-1}$ and sorgaab+brassica each @ 18 L ha$^{-1}$+glyphosate 575 g a.e. ha$^{-1}$.

**Experiment 2.** All the recorded growth and yield parameters were significantly improved by the use of crop water extracts combined with reduced rates of glyphosate except in case of monopodial branches that did not differ for sorgaab+sunflower water extract each @ 15 L ha$^{-1}$ +glyphosate @ 575 g a.e. ha$^{-1}$ as compared to control (Table IV). Higher plants were observed with glyphosate @ 2.3 kg a.e. ha$^{-1}$ followed by sorgaab+sunflower water extract each @ 15 L ha$^{-1}$+glyphosate 767 g a.e. ha$^{-1}$. More number of monopodial and sympodial branches were recorded in glyphosate @ 2.3 kg a.e. ha$^{-1}$ and were similar to sorgaab+sunflower water extract each @ 18 L ha$^{-1}$ +glyphosate @ 767 or 575 g a.e. ha$^{-1}$. Maximum number of bolls per plant and heavier bolls were recorded in glyphosate @ 2.3 kg a.e. ha$^{-1}$ and were on par with sorgaab+sunflower water extract each @ 18 L ha$^{-1}$ +glyphosate @ 767 g a.e. ha$^{-1}$. Higher rate of water extract compensated the lower rates of herbicide in number of bolls

**Table VII. Economic Analysis of cotton as influenced by sorgaab + sunflower water extract combinations with reduced rates of glyphosate**

| Parameters | $T_1$ | $T_2$ | $T_3$ | $T_4$ | $T_5$ | $T_6$ | Remarks |
|---|---|---|---|---|---|---|---|
| Seed cotton yield (kg ha$^{-1}$) | 1804 | 2108 | 2154 | 2038 | 2072 | 2147 | kg ha$^{-1}$ |
| Adjusted seed cotton yield (kg ha$^{-1}$) | 1624 | 1897 | 1939 | 1834 | 1865 | 1933 | 10% less than actual yield |
| Gross benefit (Rs. ha$^{-1}$) | 44660 | 52168 | 53323 | 50435 | 51288 | 53158 | Rs. 1100/ 40 kg |
| Cost of herbicide | - | 782 | 782 | 587 | 587 | 2347 | Round up Rs. 500/L |
| Cost of water extracts preparation | - | 150 | 180 | 150 | 180 | - | Rs. 75/15Lconc.water extract preparation |
| Labor charges of spray | - | 150 | 150 | 150 | 150 | 150 | @ Rs. 150/man ha$^{-1}$ |
| Sprayer rent | - | 60 | 60 | 60 | 60 | 60 | Rs. 60 ha$^{-1}$ |
| Cost that vary | - | 1142 | 1172 | 947 | 977 | 2557 | Rs. ha$^{-1}$ |
| Net benefits | 44660 | 51026 | 52151 | 49488 | 50311 | 50601 | Rs. ha$^{-1}$ |
| | | 14.25 | 16.77 | 10.81 | 12.65 | 13.30 | % increase over control |

$T_1$: Control (Weedy check); $T_2$: Sorgaab + sunflower each at 15 L ha$^{-1}$ + glyphosate @ 767 g a.e. ha$^{-1}$; $T_3$: Sorgaab + sunflower each at 18 L ha$^{-1}$ + glyphosate @ 767 g a.e. ha$^{-1}$; $T_4$: Sorgaab + sunflower each at 15 L ha$^{-1}$ + glyphosate @ 575 g a.e. ha$^{-1}$; $T_5$: Sorgaab + sunflower each at 18 L ha$^{-1}$ + glyphosate @ 575 g a.e. ha$^{-1}$; $T_6$: Glyphosate at 2.3 kg a.e. ha$^{-1}$ (label rate)

**Table VIII. Dominance and marginal analysis of cotton as influenced by sorgaab+sunflower water extract combinations with reduced rates of glyphosate**

| Treatments (directed post emergence 21 DAS) | Total cost that vary (Rs.) | Net benefits (Rs.) | Marginal costs (Rs.) | Marginal net benefits (Rs.) | Marginal rate of return (%) |
|---|---|---|---|---|---|
| Control (Weedy check) | 0 | 44660 | - | - | - |
| Sorgaab + sunflower each at 15 L ha$^{-1}$ + glyphosate @ 575 g a.e. ha$^{-1}$ | 947 | 49488 | 947 | 4828 | 509.82 |
| Sorgaab + sunflower each at 18 L ha$^{-1}$ + glyphosate @ 575 g a.e. ha$^{-1}$ | 977 | 50311 | 30 | 823 | 2743.33 |
| Sorgaab + sunflower each at 15 L ha$^{-1}$ + glyphosate @ 767 g a.e. ha$^{-1}$ | 1142 | 51026 | 165 | 715 | 433.00 |
| Sorgaab + sunflower each at 18 L ha$^{-1}$ + glyphosate @ 767 g a.e. ha$^{-1}$ | 1172 | 52151 | 30 | 1125 | 3750.00 |
| Glyphosate at 2.3 kg a.e. ha$^{-1}$ | 2557 | 50601 | 1385 | - | D |

D = Dominated treatment

DAS= Days after sowing; Rs. = Rupees

and boll weight. Maximum seed cotton yield was recorded for sorgaab+sunflower water extract each @ 18 L ha$^{-1}$ +glyphosate @ 767 g a.e. ha$^{-1}$, which was similar to glyphosate @ 2.3 kg a.e. ha$^{-1}$.

**Economic analysis.** The economic analysis of experiment 1 showed that sorgaab+brassica water extract each @ 18 L ha$^{-1}$ +glyphosate @ 767 g a.e. ha$^{-1}$ gave maximum net benefits of Rs. 52481/-(18.68% increase over control) followed by sorgaab+brassica water extract each @ 15 L ha$^{-1}$ +glyphosate @ 767 g a.e. ha$^{-1}$ and glyphosate @ 2.3 kg a.e. ha$^{-1}$ (16.45%; Table V). Other water extracts combinations also gave reasonable net benefits (13.28-15.98%) as compared to weedy check. Dominance and marginal analysis revealed that all the treatment combinations of sorgaab+brassica water extracts with reduced rates of glyphosate were economical with expenditure (variable cost) of only Rs. 947-1172/-per hectare and enabled the reduction in herbicide dose of 67-75% (Table VI). The most economical treatment was sorgaab+brassica water extract each @ 18 L ha$^{-1}$ +glyphosate @ 767 g a.e. ha$^{-1}$ followed by sorgaab+brassica water extract each @ 18 L ha$^{-1}$ +glyphosate @ 575 g a.e. ha$^{-1}$ with MRR of 3293% and 2100%, respectively (Table VI).

In the second experiment, sorgaab+sunflower water extract each @ 18 L ha$^{-1}$+glyphosate @ 767 g a.e. ha$^{-1}$ produced highest net benefits of Rs. 52151/-(16.77% increase over control) followed by sorgaab+sunflower water extract each @ 15 L ha$^{-1}$+glyphosate @ 767 g a.e. ha$^{-1}$ and glyphosate @ 2.3 kg a.e. ha$^{-1}$ (14.25%), respectively (Table VII). Other water extracts combinations with reduced rate of herbicide produced reasonable net benefits (10.81-13.30%) as compared to control. Dominance and marginal analysis showed that all the crop water extracts combinations with reduced rate of glyphosate were economical. The most economical treatment was sorgaab+sunflower water extract each @ 18 L ha$^{-1}$+glyphosate @ 767 g a.e. ha$^{-1}$ followed by sorgaab+sunflower water extract each @ 18 L ha$^{-1}$ +glyphosate @ 575 g a.e. ha$^{-1}$ with MRR of 3750% and 2743%, respectively (Table VIII).

## DISCUSSION

**Purple nutsedge growth.** Application of crop water extracts combined with reduced herbicides rates significantly inhibited purple nutsedge growth. The inhibition of purple utsedge growth might be due to the joint action of mixtures of allelochemicals rather than to one allelochemicals (reviewed by Einhellig, 1995). For example, Lydon *et al*. (1997) reported that soil amended with pure artemisinin was less inhibitory to the growth of red root pig weed than was soil amended with a chemically more complex annual wormwood leaf extract. This is often the case with other potent examples of allelopathic activity in higher plants (Weston & Duke, 2003). But Inderjit *et al*. (2002) found that the binary mixture of two phenolic acids (either *p*-hydroxybenzoic & ferulic acids or *p*-hydroxybenzoic & *p*-coumaric acids or *p*-coumaric & ferulic acids) was generally antagonistic and no evidence for synergistic activities of phenolic acids in the mixture was observed.

The results of the both experiments further indicated that the combination of sorgaab and brassica water extracts has more inhibitory effect on purple nutsedge than sorgaab and sunflower water extracts combinations. It might be due to the difference in type of allelochemicals present in different crop water extracts and their selective nature (Green *et al.,* 1995). Inderjit *et al.*, 2002 stated that the phenolic acids have essentially the same site of action and thus, the action could never be synergistic unless the sites were different or the compound interacted to form a new compound. Even the phytotoxins of the extracts of different parts of the same plants like leaf leachates, root exudates and soil extracts have not same compounds and this indicates that there is probably an additive effect with each group of toxins (Wilson & Rice, (1968).

This study further indicated that in most cases higher rates of crop water extracts were more effective and can reduce the herbicide dose up to 75% and was accord with Iqbal and Cheema (2007).

**Cotton growth and yield.** Different cotton growth parameters and seed cotton yield were significantly improved by the control of purple nutsedge by the use of different crop water extracts combined with reduced herbicide rates. The improvement in cotton growth, yield parameters and seed cotton yield were due to the better weed control, which enabled the crop plants to utilize the resources in better way and solar radiation without interference (Irshad & Cheema, 2004). Boquet *et al.* (2004) reported that increases in lint yield were associated with increases different yield parameters like number of bolls per plant, boll weight etc. It is also noteworthy that glyphosate @ 2.3 kg a.e. $ha^{-1}$ had no adverse effect on the cotton crop.

Economic returns were higher in the treatments having crop water extracts. The cost of production was also reduced due to herbicide reduction. The reduction in cost of production in cotton crop in Pakistan is the great achievement as it has already been increased due the higher use of insecticides to control different insects.

## CONCLUSION

The finding are according to our objectives that higher rates of extracts and different crop water extracts combination can reduce the herbicide use. Allelopathic crop water extracts have reduced the glyphosate dose up to 75% in controlling purple nutsedge. Brassica has shown comparatively better results in inhibitions of purple nutsedge than sunflower, when combined with sorgaab.

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