*Soil & Environ. 27(2): 193-201, 2008*
*www.se.org.pk*

# Rapeseed yield as influenced by fertilizer placement methods and weed control practices under rainfed conditions

***F. Zahoor[1*], M.A. Malik[1], P. Khaliq[2] and M. Rasheed[2]***
[1]Department of Agronomy, Pir Mehr Ali Shah Arid Agriculture University,Rawalpindi
[2]Plant Sciences Division, Pakistan Agriculture Research Council, Islamabad

## Abstract

*A study was conducted to investigate the effect of integrated use of fertilizer placement methods and various weed control practices on the seed yield of rapeseed during 2005-07 in Pothwar, Punjab at two locations i.e., Rawalpindi (receiving high rainfall) and Chakwal (receiving medium rainfall). Rapeseed cultivar Con-II was planted as a test crop. The experiment was conducted in randomized complete block design (RCBD) split plot arrangement with three replications. The net plot size was 4.5 m x 3.5 m. Fertilizer treatments were applied in vertical strips that were further divided to assign weed control treatments at random. Data regarding weed control treatments showed that hand weeding, inter-row hoeing and herbicide control in combination with below seed placement of fertilizer showed significant effect on weed mortality in Rawalpindi. Hand weeded plots where fertilizer was placed below the seed resulted in highest weed mortality (78%). While at Chakwal, the highest weed mortality percentage was recorded in the interaction herbicide application + once inter-row hoeing + below seed placement of fertilizer. The highest seed yield of 2325.74 kg ha$^{-1}$ was recorded in plots where inter-row hoeing was done twice and fertilizer was placed below the seed rows at Rawalpindi. At Chakwal, the highest seed yield of 1542.14 kg ha$^{-1}$ was obtained in hand weeded plots when fertilizer was applied below the seed. Weedy check treatment was at the bottom with the lowest seed yield at both locations during study period. Economic analysis indicated that farmers should use inter-row hoeing (twice) with below seed placement of fertilizer to get maximum returns at Rawalpindi. At Chakwal the interaction of herbicide application + once inter-row hoeing + below seed placement of fertilizer was very cost effective.*

**Key words:** Rapeseed, integrated weed control, fertilizer placement, herbicide, inter-hoeing

## Introduction

Pakistan is facing chronic deficit in edible oil because its domestic production is not sufficient to meet the demand of rapidly growing population of the country. Rapeseed is a major oil seed crop grown in rainfed areas of Pothwar, Punjab. It is grown on an area of 253 thousand hectares with a total national production of 149 thousand (GOP, 2006-07). Local production of edible oil stood at about 0.8 million tonnes which accounts for only 27% of total availability while the rest was met through imports. The present seed yield of rapeseed is very low due to a number of factors including low moisture content, improper fertilizer placement, weed infestation etc. It has been estimated that yield depression in rapeseed mustard due to weed infestation varies from 20-70% depending on the composition and density of weed flora and time of their occurrence (O-Donovan *et al.*, 2007). Weeds compete for soil moisture, nutrients, space and sunlight with crop plants and reduce their yield. The most prominent weeds of rapeseed are *Chenopodium album, Chenopodium murale, Anagallis arvensis, Convovulus arvensis, Euphorbia heliscopia, Medicago polymorpha, Cynodon dactylon, Phalaris minor* and *Asphodalus spp.* (Bhowmik, 2003).

In the past, farmers of Pothwar were bound to follow traditional weed techniques such as hand-pulling, hand-hoeing or mechanical hoeing. These techniques, besides being labour and energy intensive and weather dependent, are very difficult to apply due to shortage and high cost of labour. On the other hand, some farmers allow the weeds to grow to the maximum to feed their animals. This situation allows only limited weed control in field crops leading to high seed production which ultimately goes back to the soil and increases weed population manifold (Khan, 2003). The ideal principle of weed control is to prevent them before they establish. This can be done by ecological methods of control such as crop competition or smothering, which comprises of growing a heavy dense cover of some crops that will over crowed weeds and deprive them of light, water and mineral nutrients (Khan, 2001). Similarly, application of adequate fertilizer to plant crop increases their leaf growth, which facilitates earlier shading of the soil surface and thus reduces weed seed germination (Wicks *et al.,* 1995). Along other cultural techniques, management

*Email: malikfaisal_80@hotmail.com

of crop fertilization may be another important component of integrated weed management strategy. Moody (1981) has reported that fertilizer placement affects the crop's ability to compete with weeds. Placing the fertilizer where the crop has access to it, but the weeds do not allow the crop to be more competitive with weeds. He also found that deep banding of the fertilizer in rice significantly increased biomass and yield.

Integrated Weed Management (IWM) is generally the combined use of cultural, biological and herbicide measures which is not only cost effective but also environmentally sound and socially acceptable in a given situation (Smith and Reynolds, 1966). In the past, little attention has been given to improve crop productivity through IWM in rainfed areas of the Pothwar plateau. Therefore, the proposed study was carried out with the objective to develop suitable weed control technology package for rapeseed by the combined use of mechanical, herbicide and cultural weed control methods.

## Materials and Methods

The proposed study was conducted at the Experimental Farm, Pir Mehr Ali Shah, Arid Agriculture University, Rawalpindi and Barani Agriculture Research Institute, Chakwal during 2005–2007. The experiments were laid out in randomized complete block design (RCBD) in split plot arrangement with three replications. The net plot size was 4.5 m x 3.5 m. The data regarding soil physico-chemical characteristics at both sites are presented in Table 1 and 2. Mean monthly temperature during the study is summarized in Table 3. The fertilizer placement treatments were assigned in vertical strips which were further divided to assign weed control treatments at random.

**Table 1. Physico-chemical properties of experimental site at Rawalpindi**

| Characteristics | 1st year | 2nd Year |
|---|---|---|
| Textural class | Loam | Loam |
| pH | 7.60 | 7.70 |
| Organic matter (%) | 0.55 | 0.41 |
| Total nitrogen (%) | 0.063 | 0.068 |
| Available phosphorus (mg $kg^{-1}$) | 5.0 ppm | 5.5 |
| Extractable potassium (mg $kg^{-1}$) | 90.0 ppm | 99.0ppm |

Rapeseed cv. Con-II was planted as test crop. Sowing was done on 3rd week of October, 2005 and 2nd week of October, 2006 at Rawalpindi and at Chakwal in the 3rd week and 4th week of October, 2005 and 2006, respectively. The crop was sown @ 5 kg seed $ha^{-1}$. The herbicide (Atlantis) was sprayed @ 1 L $ha^{-1}$ with the help of Knapsack hand sprayer fitted with T-Jet nozzle at a pressure of 207 kp. Herbicide, mechanical and other manual treatments were applied at the 3-leaf stage of the weeds and 30 days after sowing (DAS). The most dominant weed species at Rawalpindi site were *Convolvulus arvensis, Anagallis arvensis, Chenopodium album, Melilotus indica, Medicago polymorpha, Coronopus didymus, Rumex dentatus* and *Vicia sativa*. At Chakwal, *Convolvulus arvensis, Chenopodium album, Carthamus oxyacantha* and *Asphodelus tenuifolius* were the most prominent weeds. Weed count before and after the application of treatment was made by placing the quadrate of 0.5 m x 0.5 m at random and weeds per unit area (density) was recorded.

**Table 2. Physico-chemical properties of experimental site at Chakwal**

| Characteristics | 1st year | 2nd Year |
|---|---|---|
| Textural class | Sandy Loam | Sandy Loam |
| pH | 8.00 | 8.00 |
| Organic matter (%) | 0.11 | 0.15 |
| Total nitrogen (%) | 0.038 | 0.047 |
| Available phosphorus (mg $kg^{-1}$) | 2.80 | 3.10 |
| Extractable potassium (mg $kg^{-1}$) | 111.00 | 117.00 |

The fertilizers NPK were applied at 80, 55 and 60 kg $ha^{-1}$. All the nitrogen, phosphorus and potassium were applied at the time of sowing. The crop was harvested with the appearance of the brown colour of the pods. Threshing of each plot was done separately.

The weed control treatments employed were weedy check, hand weeding, inter-row hoeing (once), inter row hoeing (twice), herbicide (Atlantis a.i. 30 g $L^{-1}$ mesosulfuron-methyl), herbicide (Atlantis) + inter-row hoeing, manual-I ("Kasola") and manual-II ("Khurpa") in integration with below seed and broadcast application of fertilizer.

Inter-row hoeing was done with the help of inter-row hoe locally manufactured and known as "tirpali" and it was employed when crop plants attained the height of about one feet. Similarly, fertilizer was placed two inches below the seed with the help of single row hand drill before the sowing of crop.

## Results

The data pertaining to various parameters such as weed mortality percentage and seed yield of rapeseed were collected and analyzed statistically. The results thus obtained are discussed in this section:

### *Weed mortality*

The data pertaining to weed mortality percentage as influenced by the interaction of various weed control

**Table 3. Monthly average temperature ($^0$C) and rainfall (mm) during the crop growth period**

| Location | Temperature ($^0$C) | | | | Rainfall (mm) | |
|---|---|---|---|---|---|---|
| | *Rawalpindi | | **Chakwal | | | |
| Year | Max ($^0$C) | Min ($^0$C) | Max ($^0$C) | Min ($^0$C) | *Rawalpindi | **Chakwal |
| Aug, 2005 | 34.2 | 23.1 | 34.3 | 23.9 | 214 | 93.2 |
| Sep | 34.0 | 22.4 | 33.9 | 22.4 | 58.6 | 85.0 |
| Oct | 31.5 | 14.8 | 31.2 | 15.1 | 54.3 | 14.0 |
| Nov | 25.5 | 7.0 | 24.7 | 6.5 | 6.3 | 3.4 |
| Dec | 21.8 | 1.1 | 20.6 | -0.4 | 0.0 | 0.0 |
| Jan, 2006 | 18.3 | 3.8 | 17.0 | 1.4 | 2.0 | 14.3 |
| Feb | 25.0 | 9.7 | 24.3 | 7.6 | 25.6 | 23.9 |
| Mar | 26.2 | 11.4 | 24.9 | 10.5 | 45.5 | 55.2 |
| Apr | 32.7 | 15.3 | 33.0 | 14.8 | 20.3 | 8.4 |
| May | 37.3 | 19.8 | 35.17 | 25.76 | 62.9 | 16.4 |
| June | 37.7 | 33.0 | 37.3 | 22.6 | 91.2 | 135.1 |
| July | 34.6 | 24.0 | 34.9 | 25.0 | 550.9 | 108.6 |
| Aug | 32.9 | 23.3 | 33.2 | 24.2 | 327.2 | 71.6 |
| Sep | 33.7 | 20.5 | 33.6 | 22.2 | 13.9 | 51.6 |
| Oct | 31.3 | 15.9 | 31.7 | 16.2 | 55.9 | 0.0 |
| Nov | 24.1 | 9.4 | 22.62 | 10.2 | 14.2 | 42.3 |
| Dec | 18.3 | 4.1 | 17.97 | 2.92 | 134.1 | 30.2 |
| Jan, 2007 | 19.7 | 1.0 | 18.6 | 0.3 | 0.5 | 0.0 |
| Feb | 19.3 | 6.6 | 18.1 | 6.8 | 93.6 | 166.0 |
| Mar | 23.1 | 9.0 | 22.8 | 9.3 | 143.2 | 147.3 |
| Apr | 35.9 | 17.9 | 35.0 | 17.5 | 19.6 | 7.8 |
| May | 39.1 | 23.0 | 39.7 | 23.4 | 79.6 | 46.14 |

Source:
*Regional Agro-meteorological Centre, Rawalpindi
**Soil and Water Conservation Research Institute, Chakwal

**Table 4. Weed mortality percentage (%) as influenced by the interaction of various weed control practices at Rawalpindi and Chakwal**

| Treatment | Locations | | | |
|---|---|---|---|---|
| | Rawalpindi | | Chakwal | |
| | Fertilizer placement methods | | | |
| | Belowseed | Broadcast | Belowseed | Broadcast |
| Weedy check | 00.00 m* | 00.00 m | 00.00 m | 00.00 m |
| Hand weeding | 78 a | 70 ab | 66 abc | 62 bcd |
| Inter-row hoe (once) | 20 i-l | 21 i-l | 17 i-l | 11 lm |
| Iinter-row hoe (Twice) | 49 def | 39 efg | 51 de | 39 efg |
| Herbicide | 55 cd | 54 cd | 32 ghi | 22 h-l |
| Herbicide + Inter-row hoe | 73 ab | 68 abc | 63 bcd | 48 def |
| Manual (Kasola) | 28 g-j | 12 lm | 13 klm | 20 i-l |
| Manual (Khurpa) | 31 g-j | 28 g-k | 36 fgh | 16 jkl |

*Any two means not sharing a letter in common differ significantly at 5% level of probability

practices at both locations showed significant results. The perusal of the data presented in Table 4 revealed that at Rawalpindi, the highest weed mortality percentage of 78% was recorded in hand weeded plots where fertilizer was placed below the seed. It was at par with the interaction of herbicide (Atlantis) application + once inter-row hoeing x below seed placement of fertilizer at the same location. Similarly, at Chakwal, the highest weed mortality

**Table 5. Weed mortality percentage (%) as influenced by the interaction of various weed control practices during 2005-06 and 2006-07**

| Treatment | Year | | | |
|---|---|---|---|---|
| | 2005-06 | | 2006-07 | |
| | Fertilizer placement methods | | | |
| | Belowseed | Broadcast | Belowseed | Broadcast |
| Weedy check | 0.0 n* | 0.0 n | 0.0 n | 0.0 n |
| Hand weeding | 69 abc | 69 abc | 75 ab | 64 bcd |
| Inter-row hoe (once) | 20 klm | 15 lm | 18 klm | 16 lm |
| Inter-row hoe (Twice) | 51 d-g | 38 g-j | 49 efg | 40 ghi |
| Herbicide alone | 25 j-m | 29 h-l | 62 b-e | 48 efg |
| Herbicide + Inter-row hoe | 57 c-f | 52 d-g | 78 a | 64 bcd |
| Manual (Kasola) | 15 lm | 14 lm | 26 i-m | 18 klm |
| Manual (Khurpa) | 24 j-m | 12 mn | 43 fgh | 32 h-k |

*Any two means not sharing a letter in common differ significantly at 5 % level of probability

**Table 6. Weed mortality percentage as influenced by the various weed control practices, fertilizer placement methods, years and locations**

| Treatment | Weed Mortality (%) |
|---|---|
| **Weed Control Practices** | |
| Weedy check | 00.00 e* |
| Hand weeding | 69 a |
| Inter-row hoe (once) | 17 d |
| Inter-row hoe (twice) | 45 b |
| Herbicide alone | 41 b |
| Herbicide + Inter-row hoe | 63 a |
| Manual (Kasola) | 18 d |
| Manual (Khurpa) | 28 c |
| **Fertilizer Placement Methods** | |
| Belowseed | 38 a* |
| Broadcast | 32 b |
| **Years** | |
| 2005-06 | 31 b* |
| 2006-07 | 39 a |
| **Locations** | |
| Rawalpindi | 39 a* |
| Chakwal | 31 b |

*Any two means not sharing a letter in common within treatments differ significantly at 5% level of probability

percentage was recorded in hand weeding x below seed interaction. It was at par with herbicide (Atlantis) application + once inter-row hoeing x below seed placement of fertilizer at the same location.

The data given in Table 5 showed significant effect of various integrated weed control practices during both years of field study. The highest weed mortality was recorded in plots where fertilizer was banded and herbicide + once inter-row hoeing was done during 2006-07. It was at par with hand weeding x below seed interaction during the same year of study. The data presented in Table 6 showed that among various weed control practices hand weeding and herbicide + once inter-row hoeing provided effective weed control. Similarly, the performance of deep banding during 2nd year of field study at Rawalpindi was better as compared to the rest of the treatments.

### *Seed yield (kg ha$^{-1}$)*

The final seed yield of a crop is the expression of combined effect of various yield components. The perusal of the data presented in Table 7 indicated significant differences for seed yield at both locations being maximum at Rawalpindi. The highest seed yield at this location was recorded in plots where fertilizer was placed below the seed and inter-row hoeing was done twice. It was at par with below seed x hand weeding and below seed x herbicide + once inter-row hoeing interaction at the same location.

Similarly, at Chakwal, the highest seed yield of 1542.16 kg ha$^{-1}$ was recorded in hand weeded plots where fertilizer was placed below the seed. It was at par with below seed x herbicide + once inter-row hoeing interaction at the same location. It may be attributed to placement of fertilizer below the seed and better weed suppression that increased nutrient supply to the plants and promoted grain nutrient contents. Ultimately, seed yield in these treatments increased significantly.

**Table 7. Seed yield (kg ha$^{-1}$) as influenced by the interaction of various weed control practices at Rawalpindi and Chakwal**

| Treatment | Location | | | |
|---|---|---|---|---|
| | Rawalpindi | | Chakwal | |
| | Fertilizer placement methods | | | |
| | Belowseed | Broadcast | Belowseed | Broadcast |
| Weedy check | 1356.27 jkl* | 1156.20 k-n | 661.96 op | 543.41 p |
| Hand weeding | 2287.22 ab | 1894.79 def | 1542.16 g-j | 1260.99 j-m |
| Inter-row hoe (once) | 1927.77 def | 1910.90 def | 1049.34 mn | 901.17 nm |
| Inter-row hoe (twice) | 2325.74 a | 2099.08 a-d | 1065.57 lmn | 1016.07 mn |
| Herbicide alone | 1808.12 d-g | 1991.16 c-f | 1281.12 j-n | 1093.55 lmn |
| Herbicide + Inter-row hoe | 2261.60 abc | 1936.72 def | 1499.88 hij | 1440.15 ijk |
| Manual (Kasola) | 2018.18 b-e | 1707.21 f-i | 1162.12 lmn | 986.41 mn |
| Manual (Khurpa) | 2024.84 b-e | 1758.33 e-h | 990.51 mn | 996.94 mn |

*Any two means not sharing a letter in common differ significantly at 5 % level of probability

**Table 8. Seed yield (kg ha$^{-1}$) as influenced by the interaction of various weed control practices during 2005-06 and 2006-07**

| Treatment | Year | | | |
|---|---|---|---|---|
| | 2005-06 | | 2006-07 | |
| | Fertilizer placement methods | | | |
| | Belowseed | Broadcast | Belowseed | Broadcast |
| Weedy check | 951.03 ij* | 765.94 j | 1067.21 hi | 933.67 ij |
| Hand weeding | 2231.58 a | 1659.92 b-e | 1597.80 c-f | 1495.86 c-g |
| Inter-row hoe (once) | 1653.75 b-e | 1459.83 d-g | 1323.37 fgh | 1352.24 e-h |
| Inter-row hoe (twice) | 1607.15 c-f | 1435.98 d-g | 1784.17 bc | 1679.17 bcd |
| Herbicide alone | 1625.42 b-f | 1686.08 bcd | 1463.83 d-g | 1398.62 d-g |
| Herbicide + Inter-row hoe | 1507.56 c-g | 1465.71 d-g | 2253.92 a | 1911.17 b |
| Manual (Kasola) | 1533.25 c-g | 1265.83 gh | 1547.05 c-g | 1427.79 d-g |
| Manual (Khurpa) | 1552.77 c-g | 1410.50 d-g | 1462.58 d-g | 1344.77 e-h |

*Any two means not sharing a letter in common differ significantly at 5% level of probability

Seed yield is interplay of yield components especially 1000-seed weight. Moreover, final seed yield greatly depends upon seasonal availability of moisture. Under rainfed conditions moisture is of great significance. The data presented in Tables 8 and 9 illustrated the interactive effect of various weed control practices on seed yield of *Brassica* during 2005-06 and 2006-07. The highest seed yield of 2253.92 kg ha$^{-1}$ was recorded in herbicide + once inter-row hoeing where fertilizer was placed below the seed during 2006-07. It was at par with hand weeded plots where fertilizer was banded deeply during the same year of study. It may be attributed to better environmental conditions that favored the crop growth during this year. Similarly, the placement of fertilizer below the seed rows helped to increase fertilizer use efficiency. Moreover, the use of various weed control practices suppressed the weeds during growth period of the crop. Ultimately, crop yield increased significantly in these treatments during 2006-07. Among the other promising weed control treatments, the integration of hand weeding x broadcast and herbicide + once inter-row hoeing x broadcast during 2$^{nd}$ year of study gave better yield as compared to rest of the treatments. The lowest seed yield of 765.91kg ha$^{-1}$ was recorded in weedy plots where fertilizer was applied as surface broadcast.

## *Economic analysis*

The dominance analysis for various weed control practices are presented in Table 10. It illustrated that treatments denoted by D are dominated as they have greater

**Table 9. Seed yield (kg ha$^{-1}$) as influenced by the various weed control practices, fertilizer placement methods, years and locations**

| Treatment | Seed yield (kg ha$^{-1}$) |
|---|---|
| **Weed Control Practices** | |
| Weedy check | 929.46 e* |
| Hand weeding | 1746.29 ab |
| Inter-row hoe (once) | 1447.30 d |
| Inter-row hoe (twice) | 1626.62 bc |
| Herbicide alone | 1543.49 cd |
| Herbicide + Inter-row hoe | 1784.59 a |
| Manual (Kasola) | 1443.48 d |
| Manual (Khurpa) | 1442.65 d |
| **Fertilizer Placement Methods** | |
| Belowseed | 1572 a* |
| Broadcast | 1418 b |
| **Years** | |
| 2005-06 | 1384 b* |
| 2006-07 | 1606 a |
| **Locations** | |
| Rawalpindi | 1904 a* |
| Chakwal | 1086 b |

*Any two means not sharing a letter in common with in treatmentdiffer significantly at 5 % level of probability

**Table 10. Dominance analysis of various weed control treatments at Rawalpindi**

| Weed Control Method | Total cost that vary | Net benefit Rs. ha$^{-1}$ |
|---|---|---|
| Weedy check | 16600 | 8520 |
| Inter-row hoe (once) | 17431 | 20949 |
| Inter-row hoe (twice) | 18262 | 25978 |
| Manual (Kasola) | 19225 | 18015 D |
| Herbicide alone | 19293 | 18687 D |
| Herbicide + Inter-row hoe | 19600 | 22380 D |
| Hand weeding | 19750 | 22070 D |
| Manual (Khurpa) | 20800 | 17040 D |
| **Fertilizer Placement Method** | | |
| Belowseed | 18100 | 21920 |
| Broadcast | 18350 | 17770 D |

variable cost but lesser net benefits, so these treatments are not subjected to marginal analysis.

The data pertaining to partial budget analysis of different weed control practices are presented in Table 11. It revealed that gross benefits of various weed control treatments ranged from Rs. 25120 ha$^{-1}$ to Rs. 44240 ha$^{-1}$. Similarly, the net benefits for different practices ranged between Rs. 8520 to Rs. 25978 ha$^{-1}$. The highest net benefits were recorded by the use of inter-row hoeing (twice) at Rawalpindi. While among different fertilizer placement methods the highest net benefit of Rs. 21920 ha$^{-1}$ was recorded with below seed placement of fertilizer at the same location. Moreover, the highest benefit cost ratio was recorded with twice inter-row hoeing and below seed placement of fertilizer at the same location.

The dominance analysis for various weed control practices is presented in Table 12. It illustrated that treatments denoted by D are dominated as they have greater variable cost but lesser net benefits, so these treatments are not subjected to marginal analysis.

The data pertaining to partial budget analysis of different weed control practices are presented in Table 13. It revealed that gross benefits of various weed control treatments ranged from Rs. 12060 ha$^{-1}$ to Rs. 29400 ha$^{-1}$. Similarly, the net benefits for different practices ranged between Rs. 1255 to Rs. 9800 ha$^{-1}$. The highest net benefits were recorded by the use of herbicide + once inter-row hoeing at Chakwal. While among different fertilizer placement methods the highest net benefit of Rs. 8620 ha$^{-1}$ was recorded with below seed placement of fertilizer at the same location. Moreover, the highest benefit cost ratio was recorded with herbicide + once inter-row hoeing and below seed placement of fertilizer at the same location.

## Discussion

The increased competitive ability of the crop with weeds is an important means of achieving improved weed management program (Liebman *et al.,* 2001). Crop fertility efficiencies can be attained through appropriate fertilizer application methods (Raun and Johnson, 1999). Research has shown that crop weed interaction can be altered by fertilizer application methods (Kirkland and Backie, 1998). The present study would aid to the identification of more efficient fertilizer placement strategies as component of comprehensive integrated weed management system. Various weed control treatments and fertilizer application methods were evaluated for crop yield and weed suppression. The highest weed mortality was recorded in plots where fertilizer was banded and herbicide + once inter-row hoeing was done during 2006-07. The highest weed mortality percentage in these plots was achieved probably due to the reason that hoe blades pushed, turned and inverted weeds at first. Moreover, application of herbicide killed weeds and provided the highest weed mortality. Also, 2006-07 was comparatively a wet year that enhanced the efficiency of herbicide and ultimately led to better weed control. Similar results have been reported by

Ashiq *et al.* (2003), who stated that herbicide efficiency is greatly influenced by environmental conditions. The moisture shortage led to photo-decomposition and volatilization of herbicides. Similarly, temperature below $10^0$C reduced herbicide efficiency due to slowing down of plant metabolism.

**Table 11. Partial budget and benefit cost ratio of different weed control practices at Rawalpindi**

| Treatment | Partial Budget | | | Benefit Cost Ratio BCR |
|---|---|---|---|---|
| | Gross benefits (Rs. ha$^{-1}$) | Total cost (Rs. ha$^{-1}$) | Net benefit (Rs. ha$^{-1}$) | |
| **Weed Control Method** | | | | |
| Weedy check | 25120 | 16600 | 8520 | 0.51 |
| Hand weeding | 41820 | 19750 | 22070 | 1.11 |
| Inter-row hoe (once) | 38380 | 17431 | 20949 | 1.20 |
| Inter-row hoe (twice) | 44240 | 18262 | 25978 | 1.42 |
| Herbicide alone | 37980 | 19293 | 18687 | 0.96 |
| Herbicide + Inter-row hoe | 41980 | 19600 | 22380 | 1.14 |
| Manual (Kasola) | 37240 | 19225 | 18015 | 0.93 |
| Manual (Khurpa) | 37840 | 20800 | 17040 | 0.81 |
| **Fertilizer Placement Methods** | | | | |
| Belowseed | 40020 | 18100 | 21920 | 1.21 |
| Broadcast | 36120 | 18350 | 17770 | 0.96 |

**Table 12. Dominance analysis of various weed control treatments at Chakwal**

| Treatment | Total cost that vary | Net benefit Rs. ha$^{-1}$ |
|---|---|---|
| **Weed Control Method** | | |
| Weedy check | 16600 | -4540 D |
| Inter-row hoe (once) | 17431 | 2069 |
| Inter-row hoe (twice) | 18262 | 2558 |
| Manual (Kasola) | 19225 | 1255 D |
| Herbicide alone | 19293 | 4447 |
| Herbicide + Inter-row hoe | 19600 | 9800 |
| Hand weeding | 19750 | 8290 D |
| Manual (Khurpa) | 20800 | -920 D |
| **Fertilizer Placement Methods** | | |
| Belowseed | 18100 | 8620 |
| Broadcast | 18350 | 4530 D |

The perusal of the data presented in Table 6 indicated that the highest seed yield at Rawalpindi was recorded in plots where fertilizer was placed below the seed and inter-row hoeing was done twice. It was probably due to the reason that deep banding of fertilizer enhanced crop growth and application of herbicide and inter-row hoeing suppressed weeds effectively. Moreover, inter-row hoeing cut the weeds, pulverized the soil, enhanced soil aeration and ultimately increased seed yield in these treatments. Furthermore, placement of fertilizer below the seed and better weed suppression increased nutrient supply to the plants and promoted grain nutrient contents at both locations. Nair *et al.* (1997), Yadav *et al.* (1997) and Bali *et al.* (1998) reported similar findings. They concluded that cultural and herbicide weed control suppressed weed growth and increased yield of *Brassica*.

The lowest seed yield at both locations was obtained in weedy plots, where fertilizer was applied as surface broadcast. It may be attributed to weed crop competition and inadequate supply of moisture and nutrients to the crop. Moreover, with broadcast application of fertilizer, nutrients probably accumulated near the soil surface and availability of NPK to crop roots was limited that decreased seed yield significantly.

Overall the highest seed yield was recorded during 2$^{nd}$ year of field study i.e. 2006-07. It may be attributed to better environmental conditions that favored the crop growth during this year. The highest benefit cost ratio was recorded with twice inter-row hoeing and below seed placement of fertilizer at Rawalpindi. At Chakwal, the highest benefit cost ratio was recorded with herbicide + once inter-row hoeing and below seed placement of fertilizer. The fact of the matter is that inter-row hoeing alone and its combination with herbicide application along with below seed placement of fertilizer suppressed weed growth during the course of the crop and ultimately

**Table 13. Partial budget and benefit cost ratio of different weed control practices at Chakwal**

| Treatment | Partial Budget | | | Benefit Cost Ratio BCR |
|---|---|---|---|---|
| | Gross benefits (Rs. ha$^{-1}$) | Total cost (Rs. ha$^{-1}$) | Net benefit (Rs. ha$^{-1}$) | |
| **Weed Control Method** | | | | |
| Weedy check | 12060 | 16600 | -4540 | -- |
| Hand weeding | 28040 | 19750 | 8290 | 0.41 |
| Inter-row hoe (once) | 19500 | 17431 | 2069 | 0.11 |
| Inter-row hoe (twice) | 20820 | 18262 | 2558 | 0.14 |
| Herbicide alone | 23740 | 19293 | 4447 | 0.23 |
| Herbicide + Inter-row hoe | 29400 | 19600 | 9800 | 0.50 |
| Manual (Kasola) | 20480 | 19225 | 1255 | 0.06 |
| Manual (Khurpa) | 19880 | 20800 | -920 | -- |
| **Fertilizer Placement Methods** | | | | |
| Belowseed | 26720 | 18100 | 8620 | 0.47 |
| Broadcast | 22880 | 18350 | 4530 | 0.24 |

provided better monetary returns. Dominance analysis presented in Table 11 illustrated interesting but realistic results regarding weed check and manual (khurpa) treatment. It can be inferred that if farmers do not employ any weed control measure like weedy check treatment they will suffer a loss of Rs. 4540 ha$^{-1}$. Similarly, employing slight weed control measure like khurpa under rainfed conditions a loss of Rs. 920 ha$^{-1}$ cannot be avoided.

## Conclusion

The results of the studies showed that farmers should use inter-row hoe (twice) with below seed placement of fertilizer to get maximum returns at Rawalpindi. At Chkawal, herbicide + once inter-row hoeing and its interaction with below seed placement of fertilizer could be effective in terms of economic benefits.

## Acknowledgements

The authors are extremely grateful to Pakistan Agricultural Research Council, Islamabad for financial support of this study under Agricultural Linkages Program (ALP). The authors also express their sincerest thanks to Director, Barani Agriculture Research Institute, Chakwal for his generous help in terms of providing labour, land and agricultural equipments etc.

## References

Ashiq, M., M.M. Nayyar and J. Ahmad. 2003. Weed control handbook. Directorate of Agronomy. Ayub Agricultural Research Institute, Faisalabad, Pakistan.

Bali, A.S., N.A. Rather, A.S. Bali, M.H. Shah and B.A. Ganai. 1998. Weed management in rapeseed (*Brassica compestris* L.) under temperate conditions of Kashmir Valley. *Indian Journal of Weed Science* 30: 25-27.

Bhowmik, T.P. 2003. Oil Seed Brassicas: Constraints and their Management. 1st Edition, CBS publishers and Distributors, New Delhi. 254p.

Government of Pakistan (GOP). 2006-07. Economic Survey 2006-2007. Economic Advisor's Wing, Finance Division, Islamabad.

Liebman, M., C.L. Mohler, C.P. Staver. 2001. Ecological Management of Agricultural Weeds. Cambridge University Press, Cambridge, U.K.

Khan, M.A. 2003. Wheat crop management for yield maximization. Agriculture Department, Lahore. Wheat Research Institute, Faisalabad.

Khan, S.R.A. 2001. Crop competition in Pakistan with focus on soil and water. Directorate of Agricultural Information, Punjab, Lahore. 394p.

Kirkland, K.J. and H.J. Backie. 1998. Contribution of nitrogen fertilizer placement to weed management in spring wheat (*Triticum aestivum*). *Weed Technology* 12: 507-514.

Moody, K. 1981. Weed fertilizer interaction in rice. International Rice Res. Institute (IRRI) International. Rice Paper Series 68, p. 35.

Nair, S.G., B.M. Path, A.P. Karunakar and H.N. Sethi. 1997. Weed control studies in irrigated mustard. *Annals of Plant Physiology* 10: 182-185.

O'-Donovan, J.T., R.E. Blackshaw, K.N. Harker, G.W. Clayton, J.R. Moyer, L.M. Dosdall, D.C. Maurice and T.K. Turkington. 2007. Integrated approaches to managing weeds in spring-sown crops in western Canada. *Crop Protection* 26: 390-398.

Raun, W.R. and G.V. Johnson. 1999. Improving nitrogen use efficiency for cereal production. *Agronomy Journal* 9: 357-363.

Smith, R.F. and H.T. Reynolds. 1966. Principal defination and scope of integrated pest control. p. 11-17. In: Proceeedings FAO Symp. Integr. Pest Control.

Wicks, G.A., O.C. Burnside and W.L. Felton. 1995. Mechanical weed management. p. 83. In: Hand book of Weed Management Systems. A.E. Smith (ed.). Marcel Dekkers, Inc., New York, USA.

Yadav, R.P., U.K. Shrivastava and K.S. Yadav. 1997. Yield and economic analysis of weed control in Indian mustard (*Brassica juncea*). *Indian Journal of Agronomy* 40: 122-124.