

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

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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*, *Convolvulus arvensis*, *Euphorbia*

heliscopia, *Medicago polymorpha*, *Cynodon dactylon*, *Phalaris minor* and *Asphodolus 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 crowd 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

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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	1 st year	2 nd 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 kPa. 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 quadrat 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	1 st year	2 nd 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 ($^{\circ}\text{C}$) and rainfall (mm) during the crop growth period

Location	Temperature ($^{\circ}\text{C}$)				Rainfall (mm)	
	*Rawalpindi		**Chakwal		*Rawalpindi	**Chakwal
Year	Max ($^{\circ}\text{C}$)	Min ($^{\circ}\text{C}$)	Max ($^{\circ}\text{C}$)	Min ($^{\circ}\text{C}$)		
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
Inter-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 $1542.16 \text{ kg ha}^{-1}$ 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 2nd 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 treatment differ 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 and application of herbicide and inter-row hoeing

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

greatly influenced by environmental conditions. The moisture shortage led to photo-decomposition and volatilization of herbicides. Similarly, temperature below 10°C reduced herbicide efficiency due to slowing down of plant metabolism.

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

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 2nd 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.

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