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Yield and Yield Components of Cowpea as Affected by Various Weed Control Methods under Rain-fed Conditions of Pakistan

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ABSTRACT

A field study was conducted at National Agricultural Research Centre (NARC), Islamabad, during two crop years (2003 - 04) to determine the effect of different weed control methods on the yield and yield components of cowpeas. In this study different weed control methods (chemical, mechanical, hand-weeding & their integration) were compared for their efficiency to control various weed species under rain-fed conditions of Pakistan. Among different weed control methods, chemical-weeding (Stomp @ 3.75 L ha^{-1}) at 2 - 3 leaf stage of weeds + hand-weeding at 50 DAS gave promising results. This was closely followed by mechanical weeding after 20 days of crop sowing. Maximum reduction in density and biomass of the weeds was observed by chemical-weeding at 2 - 3 leaf stage of weeds + hand-weeding at 50 DAS. There was a significant increase (68%) in grain yield of cowpea due to chemical-weeding at 2 - 3 leaf stage of weeds + hand-weeding at 50 DAS. Similarly, this treatment out yielded other treatments in terms of number of pods per plant, number of seeds per pod, 1000 grain weight, plant biomass and grain yield. The economic analysis of these weed control methods also showed better performance of chemical-weeding at 2 - 3 leaf stage of weeds + hand-weeding at 50 DAS as compared to rest of the treatments.

Key Words: Cowpea; Weeds; Integrated weed control; Yield components

INTRODUCTION

Cowpea (*Vigna unguiculata* L.) sown in summer season is infested by a number of weed species that compete with the crop right from germination to harvest, affecting the crop yield adversely (Yadav *et al.*, 1998). Thus to enhance crop yield and its effect on soil fertility, the control of weeds in summer crop is very important. The conventional method of weeding such hoeing, hand-weeding and harrowing is expensive and labour is not available during peak workload (Khan *et al.*, 2000). Therefore the use of herbicides in cowpea to control weeds appears to be useful (Dadari, 2003; Silva, 2003). In general herbicides are effective only against few weed species, which results in serious infestation of other weeds. Weeds are of negative values, which lower the input efficiency. Apart from increasing the production cost, they also intensify disease and insect pest problem by serving as alternative hosts. Besides quantitative effects on yield, weeds deteriorate the quality of produce through the physical presence of their seeds and debris. Weed density, type of the weeds, their persistence and crop management practices determine the magnitude of yield loss. Yield loss in cowpea due to weeds was 12.7 - 60.0% (Li *et al*., 2004). The phenomenon involved in crop yield increase as affected by different weed control method have already been well described by Bukhtiar *et al.* (1991), Rao *et al.* (1992), Mathew and Sreenivasan (1998), Tomar *et al.* (2003) and Patel *et al.* (2003). Tripathi and Singh (2001) reported that presence of weeds in cowpea reduced yield by 82% and significant increase in pod yield was noted by controlling weeds up to 45 days of sowing.

Parasuraman (2000) found that application of pendimethalin (1.5 or 2.0 L ha^{-1}) or fluchloralin (1.0 or 1.5 L ha^{-1}) at 3 days + hand-weeding twice at 30 DAS resulted in significant reduction in weed population and weed dry matter and increased in crop yield in rain-fed cowpea. Patel *et al.* (2003) conducted field experiment to evaluate weed management strategy for cow pea. Pre-emergence application of pendimethalin at 0.75 kg a.i. ha^{-1} + weeding at 5 week after sowing gave a higher grain yield (511 kg ha^{-1}) and net return (Rs. 4705 ha^{-1}) compared to other treatments. According to Silva (2003) the best post emergence weed control in cowpea was provided by phenoxaprop-p-ethyl at the rate of 80 g ha^{-1}, associated with glyphosate (1800 g ha^{-1}) and it was more effective against grasses. Jaibir *et al*. (2004) reported that pendimethalin at 1.0 kg ha^{-1} + hand-weeding at 30 DAS gave the highest cowpea yield and weed density and dry biomass was lowest in this treatment.

In barani areas of Pakistan, none of the weed control methods is best under all conditions. So, there is a need to make a comparative study of different weed management techniques in cowpea and to develop an integrated weed management approach, which should be efficient and cost effective and environmentally safe. The postulation that integration of different weed control methods may be useful to provide better weed control in cowpea can be assessed. Keeping these facts in view, a comprehensive study was planned to integrate different weed control methods in rain-fed cowpea crop. The effect of different weed control

methods was studied on yield and yield component of cowpeas in wheat-cowpeas-wheat crop rotation during 2002 - 04.

MATERIALS AND METHODS

The field experiment was conducted under rain-fed conditions for two crop years (2002 - 03 & 2003 - 04) at National Agricultural Research Centre (NARC), Islamabad. Soils of the area are loess in nature, slightly alkaline with pH 8.2 and low in organic matter (0.5%). The mean maximum temperature during the experiment was 40°C, while the mean minimum temperature was 14°C. The mean annual rain-fall, were 840 and 550 mm during 2003 and 2004, respectively.

The experiments were laid out in RCBD with 3 replications. Six weed control methods were included in the study. These were weedy check (WC_1), hand-weeding at 20 and 40 DAS (WC_2), mechanical weeding at 20 DAS (WC_3), chemical-weeding (WC_4) at 2 - 3 leaf stage of weeds, mechanical weeding at 20 days after sowing + hand-weeding at 50 DAS (WC_5) and chemical-weeding at 2 - 3 leaf stage of weeds + hand-weeding at 50 DAS (WC_6). Mechanical weeding was carried out by using local implement "Tarphali". Commonly used herbicide Stomp 330 E (pendimethalin) was obtained from local market and applied @ 3.75 L ha^{-1} at 2 - 3 leaf stage. Volume of spray (300 L ha^{-1}) was determined by calibration as described by Rao (1983). Spraying was done with Knapsack hand sprayer fitted with T-Jet nozzle maintaining a pressure of 207 kp.

A local recommended variety of cowpeas was collected from Oilseed Research Program, Crop Sciences Institute, NARC, Islamabad. It was sown in first week of July, 2003 and 2004. Recommended seed rate (25 kg ha^{-1}) was used to plant this crop in 25 cm apart rows. All other agronomic operations except those under study were kept normal and uniform for all the treatments.

Standard procedures were adopted for recording the data on various growth and yield parameters. Species wise weed population was counted at random from an area of one m^2 from each plot. The counted weeds were cut from ground surface, stored in polythene bags and then brought to laboratory for recording their biomass. The dry weight of each weed species was determined after oven-drying at 70°C until constant weight was achieved. The height of ten plants was recorded at random from the ground to the apex of the plants in each plot and then average was taken. Total number of pods from the ten randomly selected plants was counted and average for per plant was taken. Ten pods were taken randomly to determine the number of seed pod^{-1}. Average number of seeds per pod was calculated. One thousand seeds were taken from each plot yields and were weighed. Plants from an area of 0.25 square meter were harvested, weighed, oven dried at 65°C for 24 h and then dry weight was recorded. Two samples of one square meter were taken from centre of each plot at random. Plants were threshed manually; grain yield of each plot was recorded and converted into kilograms $hectare^{-1}$. Harvest index of mungbean was calculated as ration of grain yield to biological in %. Data collected were statistically analyzed by using the Fisher's Analysis of Variance technique and Duncan`s New Multiple Range (DNMR) test at 0.05 P was applied to compare the differences among treatments (Steel & Torrie, 1984).

RESULTS

Weed density and dry biomass. *Trianthema monogyna, Cyperus rotundus, Sorghum halepense, Digera arvensis, Echinochloa colona* and *Cynodon dactylon* were the main weed species found in cowpea field. A significant difference between years regarding the density of *Trianthema monogyna, Cyperus rotundus, Sorghum halepense* and *Digera arvensis,* was recorded being minimum during the second year. The effect of years on density of *Echinochloa colona* and *Cynodon dactylon* was found to be non-significant (Table I). Data regarding effect of different weed control methods on weeds density at maturity showed that chemical-weeding (stomp 330 E @ 3.75 l ha^{-1}) + hand-weeding at 50 DAS resulted in maximum reduction in density of the aforementioned weeds. Comparatively less reduction in weed density was observed with WC_3 and WC_4. The effect of years on dry biomass of weeds was found to be non-significant (Table II). The dry biomass of *Trianthema monogyna, Cyperus rotundus* and *Sorghum halepense*, was maximum reduced with the treatment WC_6, while dry biomass of *Digera arvensis, Echinochloa colona* and *Cynodon dactylon* was maximum suppressed by WC_5, WC_2 and WC_5, respectively (Table II).

Yield component and yield of cowpea. The data of Table III show that the year effect on plant height, number of pods $plant^{-1}$ number of seeds per pod and 1000 grain weight was found non-significant. While a significant difference in plant biomass, grain yield and harvest index was recorded during both years.

Plant height of cowpea at maturity was affected significantly by different weed control methods. Maximum plant height (100.33 cm) was noted with weed control method WC_6. Combination of mechanical weeding and hand-weeding (WC_5) was the next better treatment and resulted in taller plants. Various weed control methods showed significant increase in number of pods $plant^{-1}$ of cowpeas. Maximum number of pods $plant^{-1}$ was recorded with WC_6 and WC_5 during both years of study. On an average, maximum number of seeds pod^{-1} (12.50) was recorded with WC_6 followed by WC_2 (11.33) that was similar to WC_5 (11.67). Rest of the treatments showed less number of seeds pod^{-1}, but was significantly better as compared to WC_1 during both study years.

Table I. Effect of various weed control methods on density (m^{-2}) of different weeds of cowpea

Treatments	Trianthema monogyna	Cyperus rotundus	Sorghum halepense	Digera arvensis	Echinochloa colona	Cynodon dactylon
a. Years						
Y_1	15.96a*	14.50a*	31.34a*	14.06a*	29.06NS	37.47NS
Y_2	15.00b	14.31b	30.44b	13.40b	29.76	37.56
			b. Weed Control Methods			
WC_1	63.00a*	40.17a*	145.83a*	42.67a*	27.83 a*	101.17a*
WC_2	7.00c	5.00b	13.50c	4.50c	2.83 d	16.50c
WC_3	14.00b	4.50b	31.83b	9.83b	8.17 b	21.83b
WC_4	11.67b	5.00b	27.67b	6.17c	4.83 c	27.00b
WC_5	9.17c	2.33b	10.17c	4.17c	2.83 d	12.00c
WC_6	5.50d	2.00b	8.17c	3.67c	2.83 d	13.00c

Y_1=1st year, Y_2=2nd year, WC_1= Weedy Check, WC_2= Hand Weeding at 20 and 40 DAS, WC_3= Mechanical Weeding (Tarphali) at 20 DAS, WC_4= Chemical Weeding (Pendimethalin, Stomp) at 2-3 leaf stage of weeds, WC_5= Mechanical Weeding at 20 DAS + Hand Weeding at 50 DAS, WC_6= Chemical Weeding at 2-3 leaf stage of weeds + Hand Weeding at 50 DAS; * Means not sharing a letter in common within treatments differ significantly at 5% probability level; NS = Non significant

Table II. Effect of various weed control methods on dry biomass (g m^{-2}) of different weeds of cowpea

Treatments	Trianthema monogyna	Cyperus rotundus	Sorghum halepense	Digera arvensis	Echinochloa colona	Cynodon dactylon
a. Years						
Y_1	6.78NS	5.13NS	26.42NS	11.31NS	17.02NS	28.99NS
Y_2	6.68	5.06	25.71	10.69	16.88	27.47
			b. Weed Control Methods			
WC_1	29.78a*	12.59a*	108.00a*	31.25a*	13.84a*	86.22a*
WC_2	2.90c	1.69b	13.01c	4.07c	1.62d	10.65c
WC_3	6.96b	1.75b	28.42b	9.10b	5.12b	18.03b
WC_4	4.39c	1.77b	26.20b	5.88c	2.83c	16.04b
WC_5	4.29c	1.03b	10.85c	3.18d	1.67d	9.78c
WC_6	2.80c	0.94b	9.00c	3.27d	2.19c	9.83c

Y_1=1st year, Y_2=2nd year, WC_1= Weedy Check, WC_2= Hand Weeding at 20 and 40 DAS, WC_3= Mechanical Weeding (Tarphali) at 20 DAS, WC_4= Chemical Weeding (Pendimethalin, Stomp) at 2-3 leaf stage of weeds, WC_5= Mechanical Weeding at 20 DAS + Hand Weeding at 50 DAS, WC_6= Chemical Weeding at 2-3 leaf stage of weeds + Hand Weeding at 50 DAS; * Means not sharing a letter in common within treatments differ significantly at 5% probability level; NS = Non significant

Table III. Effect of various weed control methods on yield and yield components of cowpea

Treatments	Plant height (cm)	No. of pods $plant^{-1}$	No. of seeds pod^{-1}	1000-grain wt. (g)	Plant biomass (tonnes ha^{-1})	Grain yield (tonnes ha^{-1})	Harvest Index (%)
a. Years							
Y_1	95.44NS	14.28NS	10.94NS	55.94NS	2.942b*	0.998b*	33.12b*
Y_2	95.94	14.50	11.11	56.61	3.272a	1.090a	33.80a
				b. Weed Control Methods			
WC_1	89.50e*	12.00c*	9.67d*	50.00d*	2.505e*	0.765e*	30.49c*
WC_2	97.33b	14.50b	11.33b	58.00b	3.184c	1.071c (40.0)[2]	33.59b
WC_3	93.50d	13.50b	10.33c	55.17c	2.782d	0.945d (23.5)	33.95ab
WC_4	95.17c	14.50b	10.67c	56.33c	3.030c	1.023c (33.7)	33.78ab
WC_5	98.33b	15.67a	11.67b	58.33b	3.426b	1.177b (53.9)	34.37ab
WC_6	100.33a	16.17a	12.50a	59.83a	3.716a	1.285a (68.0)	34.60a

Y_1=1st year, Y_2=2nd year, WC_1= Weedy Check, WC_2= Hand Weeding at 20 and 40 DAS, WC_3= Mechanical Weeding (Tarphali) at 20 DAS, WC_4= Chemical Weeding (Pendimethalin, Stomp) at 2-3 leaf stage of weeds, WC_5= Mechanical Weeding at 20 DAS + Hand Weeding at 50 DAS, WC_6= Chemical Weeding at 2-3 leaf stage of weeds + Hand Weeding at 50 DAS

* Means not sharing a letter in common within treatments differ significantly at 5% probability level; NS = Non significant; [2]% increase compared with control

Similarly maximum 1000-grain weight of cowpeas (59.83 g) was obtained with WC_6 followed (58.33 g) by WC_5 and (58.00 g) WC_2. The performance of WC_3 and WC_4 was statistically lower as compared to rest of the weed control methods. Among various weed control treatments, WC_6 resulted in maximum plant biomass (3.716 tonnes ha^{-1}) as compared to rest of the treatments. The highest grain yield (1.285 tonnes ha^{-1}) of cowpea was harvested with WC_6 followed (1.177 tonnes ha^{-1}) by WC_5. A significant difference in harvest index value of cowpeas between study years being maximum during the second year. This might be due to the maximum yield obtained during this year. The harvest index of cowpea as affected by different weed control methods was also found significant during both years of study. Examination of the data revealed that maximum % value (34.60%) was calculated with WC_6 followed by rest of the treatments. The rest of weed control methods showed lower value of harvest index of the crop during this year and all weed control methods were found statistically similar and higher than that of WC_1 treatment.

All the treatments gave higher net benefit as compared to control (Table IV). The treatments WC_6 (chemical-weeding at 2 - 3 leaf stage of weeds + hand-weeding at 50 DAS) resulted in higher net benefit (Rs. 70172 ha^{-1}). The treatment WC_3 (Mechanical Weeding at 20 DAS) had less net benefits (Rs. 54532 ha^{-1}). But in case of marginal analysis (Table V) mechanical weeding at 20 DAS (WC_3) was found better than all the treatments with maximum

marginal rate of return (1304%). The treatment WC_2 (hand-weeding at 20 & 40 DAS) and WC_4 (chemical-weeding at 2 - 3 leaf stage of weeds) was dominated due to less net benefit and higher cost that varied, so it was un-economical treatment at the prevailing crop and herbicide prices. On the basis of this study it is suggested that chemical-weeding at 2 - 3 leaf stage of weeds + hand-weeding at 50 DAS or Mechanical Weeding at 20 DAS may be used for controlling weeds in wheat with fairly good economic returns.

DISCUSSION

For determining a suitable weed control strategy to enhance cowpea productivity by integrating various weed control methods was the primary aim in this experiment. Findings suggest that use of stomp @ 3.75 L ha^{-1} + hand-weeding at 50 DAS were quite suitable combinations in controlling most of cowpea weeds and to increase its productivity. In general application of herbicide (stomp 330 E) along with hand-weeding was effective against cowpea weeds. Mechanical weeding through the use of tarphali along with hand-weeding was the next better combination, which controlled cowpea weeds effectively. Combination of these weed control methods decreased more weed biomass suggesting that integrating the weed control strategies enhanced their weed inhibitory capability.

Healthy growth of cowpeas plants in case of WC_6, WC_5 and/or WC_2 probably resulted from effective weed control causing maximum nutrient utilization by the crop plants and hence maximum plant height. Application of herbicide or use of tarphali along with hand-weeding (WC_6 & WC_5) increased number of pods $plant^{-1}$ of cowpeas by 33 and 31%, respectively which might be due to weed suppression resulting healthy plant growth and ultimately more pod formation. The treatment WC_6 caused about 20% increase in 1000-grain weight followed by 16% with WC_5. Plant biomass of cowpeas was statistically significant during both years being maximum with second year. The reason might be the healthy crop stand, because of affective weed suppression in this year. Approximately 44% increase in plant biomass due to the treatment WC_6 over control was recorded. It may be attributed to suppression of weeds that resulted in good crop stand utilizing maximum crop plant nutrients and hence comparatively higher plant biomass of cowpea. The weed control method WC_3 produced the lowest plant biomass (2.783 tonnes ha^{-1}) as compared to rest of the treatments. Comparatively less efficiency of this treatment might be due to competition between weeds re-emerged later on and crop plants for plant nutrients resulting in poor crop growth and hence minimum plant biomass. Similarly a significant difference in grain yield of cowpeas between study years being maximum during the second year. This might be due to minimum weed seed bank in soil effective and eradication of weeds during that year. The treatments such as WC_6 and WC_5 caused about 52% and 14% increase in grain yield, respectively as compared to control (WC_1) treatment. The weed control methods WC_3 produced comparatively lower grain yield of cowpea. Comparatively less efficiency of this method probably was due to re-emergence of weeds that increased crop competition for inputs, which ultimately lead to low assimilation of photosynthetic, causing direct effect on grain yield reduction of cowpea.

Table IV. Economic analysis of various weed control treatments in cowpea

	WC_1	WC_2	WC_3	WC_4	WC_5	WC_6	Remarks
Total cowpea grain yield for two Year	1530.0	2142.0	1890.0	2046.0	2354.0	2570.0	kg ha^{-1}
10% less (than actual yield)	153.0	214.2	189.0	204.6	235.4	257.0	kg ha^{-1} (to bring it at farmer level)
Adjusted yield	1377.0	1927.8	1701.0	1841.4	2118.6	2313.0	kg ha^{-1}
Gross income (ha^{-1})	44752.5	62653.5	55282.5	59845.5	68854.5	75172.5	Cowpea grain Price @ 32.50/kg
Hand Weeding	0.0	3000.0	0.0	0.0	1500.0	1500.0	Rs.100/man (one man /day/ha).
Mechanical weeding	0.0	0.0	750.0	0.0	750.0	0.0	Rs. 750 ha^{-1}
Cost of herbicide	0.0	0.0	0.0	3200.0	0.0	3200.0	Stomp Rs.1600/ha. Expenses for two years
Spray application cost	0.0	0.0	0.0	200.0	0.0	200.0	Rs.100 man^{-1} (one man /day/ha)
Spray rent	0.0	0.0	0.0	100.0	0.0	100.0	Rs.50 $spray^{-1}$
Cost that vary	0.0	3000.0	750.0	3500.0	2250.0	5000.0	Rs. ha^{-1}
Net benefit	44752.5	59653.5	54532.5	56345.5	66604.5	70172.5	Rs. ha^{-1}

WC_1= Weedy Check, WC_2= Hand Weeding at 20 and 40 DAS, WC_3= Mechanical Weeding at 20 DAS, WC_4= Chemical Weeding (Pendimethalin, Stomp) at 2-3 leaf stage of weeds, WC_5= Mechanical Weeding (Tarphali) at 20 DAS + Hand Weeding at 50 DAS, WC_6= Chemical Weeding at 2-3 leaf stage of weeds + Hand Weeding at 50 DAS

Table V. Marginal rates for various weed control treatments in cowpea

Treatments	Total cost that vary[1] (Rs. ha^{-1})	Net benefits[2] (Rs. ha^{-1})	Marginal rate of return[3] (%)
WC_1 (Weedy Check)	0.0	44752.5	
WC_3 (Mechanical Weeding at 20 DAS)	750.0	54532.5	1304.0
WC_5 (Mechanical Weeding at 20 DAS + Hand Weeding at 50 DAS)	2250.0	66604.5	804.8
WC_2 (Hand Weeding at 20 and 40 DAS)	3000.0	59653.5	0
WC_4 (Chemical Weeding at 2-3 leaf stage of weeds)	3500.0	56345.5	0
WC_6 (Chemical Weeding at 2-3 leaf stage of weeds + Hand Weeding at 50 DAS)	5000.0	70172.5	237.9

[1] The sum of all the costs that vary for a particular treatment; [2]The difference between total costs that vary and the gross benefit for each treatment; [3]The ratio of marginal net benefits and marginal costs expressed as percentage; [4]Dominated treatment, the treatment which have higher costs but lower net benefits

The increase in crop yield and yield components as a result of weeds has been well documented by Tiwari *et al.* (1984). In a field study on cowpeas Patel *et al.* (2003) reported [comparing weed control, chemical weed control, manual weeding at 3 weeks after sowing, interculturing (IC) at 3 weeks after sowing (WAS), chemical + hand-weeding at 5 WAS, chemical + IC at 5 WAS and weed free control at 45 cm row spacing] that chemical + hand-weeding at 5 WAS produced maximum number of pods plant^{-1} of cowpeas. Similar conclusion has also been drawn by Roslon and Fogelfors (2003) that proper weed management gave higher yields of crops. The phenomenon involved in crop yield increase as affected by different weed control method have already been well described by Bukhtiar *et al.* (1991), Rao *et al.* (1992), Mathew and Sreenivasan (1998), Tomar *et al.* (2003) and Patel *et al.* (2003). These results are in accordance with Margin *et al.* (1984), Liebl and Worsham (1987), Ahmad *et al.* (1990) and Khan *et al.* (1991a). Rana and Pal (1997), who reported that hand-weeding 15 and 30 days after sowing produced higher grain yield of cowpeas than with fluchloralin chemical-weeding.

On the basis of these results it can be concluded that maximum reduction in density and biomass of the weeds was observed by chemical-weeding (stomp 330 E @ 3.75 L ha^{-1}) at 2 - 3 leaf stage of weeds + hand-weeding at 50 DAS (WC_6). There was a significant increase (68%) in grain yield of cowpea due to chemical-weeding at 2 - 3 leaf stage of weeds + hand-weeding at 50 DAS (WC_6). Similarly, this treatment (WC_6) out yielded other treatments in terms of number of pods per plant, number of seeds per pod, 1000 grain weight, plant biomass, grain yield and net benefits.

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