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Integrated Weed Management in Pigeonpea [*Cajanus cajan* (L.) Millsp.]

Guriqbal Singh and H.S. Sekhon

Department of Plant Breeding and Genetics,
Punjab Agricultural University, Ludhiana 141004, Punjab, India

Abstract: Uncontrolled weeds cause considerable losses in the grain yield of pigeonpea. Field experiments were conducted for seven years from 1998 to 2004 on a loamy sand soil to study the effect of weed management on weeds, growth and grain yield of pigeonpea. In some years, weed dry matter was higher than in others, due to variation in rainfall received. Two hand weedings, pendimethalin in integration with hand weeding or ridging or both and paraquat in integration with hand weeding resulted in high weed control efficiency. Uncontrolled weeds caused 31.0 to 52.8% reduction in pigeonpea grain yield in different years. The sole application of pendimethalin as pre-emergence at 45 or 75 kg ha^{-1} was less effective in controlling weeds and improving grain yield than the above mentioned treatments as pigeonpea is a long duration (about 140 days) crop and weeds emerge in different flushes due to rainy season. Integration of pendimethalin 0.45 kg ha^{-1} + hand weeding 30 DAS + ridging 50 DAS provided the high weed control efficiency and produced the highest grain yields of pigeonpea in all the years of study.

Key words: Weeds · Weed control efficiency · Hand weeding · Pendimethalin · Paraquat

INTRODUCTION

Pigeonpea [*Cajanus cajan* (L.) Millsp.] is one of important grain legume crops in the world, which was grown globally in 2010 on 4.75 million hectares with total production of 3.68 million tonnes [1]. India, Myammar, Malawi, Kenya, Uganda and Tanzania are the major pigeonpea producing countries. India with 3.53 million ha area under pigeonpea and 2.46 million tonnes production ranks first in the world.

In India, pigeonpea is grown during kharif (rainy season). Due to rainy season, slow initial growth and sowing at wider row spacing, severe infestation of weeds is observed in pigeonpea which results in low grain yield. Reduction in yield due to weeds in pigeonpea to the tune of 55-60% has been reported [2]. Therefore, it is imperative to control weeds at proper time and with suitable method(s) to obtain high grain yields of pigeonpea.

Weeds in pigeonpea can be controlled effectively with hand weeding twice at 3 and 6 weeks after sowing [3]. However, due to frequent rains it becomes difficult to do hand weeding at proper time. Furthermore, non-availability of labour for hand weeding is another problem. So there is a need to find effective weed control techniques using herbicides. In pigeonpea, initial six weeks period is the critical period of the crop-weed competition. Therefore, weeds must be controlled during this period for obtaining high grain yields. Pre-emergence herbicides may help in checking weed growth during this period. Pendimethalin, as pre-emergence, has been found promising in controlling weeds and improving pigeonpea yield [4]. However, it is effective only up to about a month and thereafter weeds may pose a problem. Therefore, integrated use of pendimethalin with hand weeding or ridging may help in achieving season-long weed control. Integrated weed management provides effective weed management in pigeonpea [4-6] and cowpea (15). Weeds need to be monitored for the correct timing of herbicide application (14)

Some times, farmers miss the application of pre-emergence herbicide and later on find it difficult to control weeds manually. Under such situations, post-emergence application of herbicides may help in alleviating weed problem. Some of the herbicides may be phytotoxic to pigeonpea at some rate of application [2,7] or to the succeeding crop [8]. Therefore it becomes imperative to

Corresponding Author: Dr. Guriqbal Singh, Department of Plant Breeding and Genetics,
Senior Agronomist (Pulses), Pulses Section, Punjab Agricultural University,
Ludhiana 141004, India.

screen herbicides at different rates of application which are safe to the crop and at the same time provide effective weed management.

Therefore, field experiments were conducted to find out effective weed control measures in pigeonpea using integrated mechanical and chemical weed control measures.

MATERIALS AND METHODS

Site Characterization: Field experiments were conducted for seven years from 1998 to 2004 during kharif (rainy) season at Punjab Agricultural University, Ludhiana, India to find out integrated weed management in pigeonpea. The soil of the experimental site was loamy sand, having pH 8.2 and was low in available nitrogen and medium in available phosphorus and potash. Data on rainfall received during the crop growing season are presented in Table 1.

Crop Husbandry: The crop was raised as per the details given in Table 2. Prior to sowing irrigation was applied and at proper moisture conditions the field was prepared by cultivating twice followed by planking. The crop was irrigated as per the need. Thiodan 35 EC (endosulfan) was sprayed @ 2.5 l ha^{-1} at pod development against pod borer complex.

Treatments: Seven treatments during 1998, 1999, 2000, 2003 and 2004 and 11 treatments during 2001 and 2002, as listed in Tables 3-5, were tested in a randomized complete block design. In case of one and two hand weedings, weeds were removed 30 and 30+50 days after sowing (DAS) manually using hand operated small implement *khurpa*. In case of pendimethalin treatments, the herbicide was sprayed at rates as per the treatment, on the same day or one day after sowing using knapsack sprayer fitted with flood jet nozzle using 500 litres of water per ha. Thus pendimethalin was sprayed after sowing but before the emergence of weeds and the crop. In case of ridging treatments, earthening up was done manually using spade 50 DAS, which not only controlled weeds but also supported plants. In case of paraquat treatments, the herbicide was sprayed at different timings as per the treatment as directed spray between the rows using 500 litres of water per ha and using a plastic hood to avoid drift. Paraquat is a broad spectrum herbicide and kills all green matter. Therefore, care was taken that the herbicidal solution could not fall on pigeonpea plants, which were sown in rows 50 cm apart, by using a plastic hood to ensure directed spray on weeds only between the crop rows and to avoid drift on the crop plants while spraying.

Table 1: Rainfall received during crop growing season in different years of the study

Month	1998	1999	2000	2001	2002	2003	2004	Long term average rainfall (mm)
June	91.4	21.4	89.2	221.0	0.0	0.0	55.4	66.4
July	442.6	359.2	232.1	383.8	36.8	180.6	33.2	232.1
August	63.5	68.6	121.0	213.5	24.5	297.7	213.9	179.7
September	183.9	94.8	139.9	28.6	193.0	52.2	2.6	101.8
October	133.2	0.0	0.0	0.0	2.2	0.0	33.0	6.0
Total	914.6	544.0	582.2	846.9	256.5	530.5	338.1	586.0

Table 2: Treatments and crop husbandry details of experiments during 1998 to 2004

Particulars	1998	1999	2000	2001	2002	2003	2004
Number of treatments	7	7	7	11	11	7	7
Replications	3	3	3	4	4	4	4
Plot size (m^2)	5×4	6×3	6×3	5×4	6×3	6×3	5×4
Date of sowing	3 June	11 June	8 June	6 June	5 June	17 June	14 June
Variety	AL 201	AL 201	AL 201	AL 201	AL 201	AL 201	AL 201
Seed rate (kg ha^{-1})	15	15	15	15	15	15	15
Row spacing (cm)	50	50	50	50	50	50	50
Date of harvest	10 Nov.	1 Nov.	24 Oct.	2 Nov.	27 Oct.	30 Oct.	5 Nov.

Table 3: Effect of weed control treatments on dry matter of weeds in pigeonpea at harvest

		Dry matter of weeds (kg ha^{-1})						
Sr. No.	Treatment	1998	1999	2000	2001	2002	2003	2004
1	Unweeded Control	2822	2756	3800	3504	1996	2641	2400
2	One hand weeding 30 DAS	1478	1380	1133	-	-	-	-
3	Two hand weedings 30+50 DAS	470	455	533	533	387	472	516
4	Pendimethlin 0.45 kg ha^{-1} (pre-emergence)	-	-	-	1291	588	1025	2216
5	Pendimethlin 0.75 kg ha^{-1} (pre-emergence)	598	587	777	1073	506	640	2066
6	Pendimethlin 0.45 kg ha^{-1} (pre-emergence) + Hand weeding 30 DAS	485	502	444	497	401	580	733
7	Pendimethlin 0.45 kg ha^{-1} (pre-emergence)+ Ridging 50 DAS	512	509	422	435	409	510	666
8	Pendimethlin 0.45 kg ha^{-1} (pre-emergence) + Hand weeding 30 DAS + Ridging 50 DAS	406	487	222	340	302	430	616
9	Paraquat 0.48 kg ha^{-1} 25 DAS	-	-	-	1524	882	-	-
10	Paraquat 0.48 kg ha^{-1} 25 DAS + Hand weeding 50 DAS	-	-	-	493	406	-	-
11	Paraquat 0.48 kg ha^{-1} 6 WAS	-	-	-	888	706	-	-
12	Paraquat 0.48 kg ha^{-1} 8 WAS	-	-	-	791	689	-	-
	C.D. 5%	318	282	311	147	208	378	202

DAS: Days after sowing
WAS: Weeks after sowing
-: Not tested

Table 4: Effect of weed control treatments on weed control efficiency in pigeonpea

		Weed control efficiency (%)						
Sr. No.	Treatment	1998	1999	2000	2001	2002	2003	2004
1	Unweeded Control	-	-	-	-	-	-	-
2	One hand weeding 30 DAS	47.6	49.9	70.1	-	-	-	-
3	Two hand weedings 30 + 50 DAS	83.3	83.4	85.9	48.6	80.6	82.1	78.5
4	Pendimethlin 0.45 kg ha^{-1} (pre-emergence)	-	-	-	63.1	70.5	61.1	7.6
5	Pendimethlin 0.75 kg ha^{-1} (pre-emergence)	78.8	78.7	79.5	69.3	74.6	75.7	13.9
6	Pendimethlin 0.45 kg ha^{-1} (pre-emergence) + Hand weeding 30 DAS	82.8	81.7	88.3	85.8	79.9	78.0	69.4
7	Pendimethlin 0.45 kg ha^{-1} (pre-emergence) + Ridging 50 DAS	81.8	81.5	88.8	87.5	79.5	80.6	72.2
8	Pendimethlin 0.45 kg ha^{-1} (pre-emergence) + Hand weeding 30 DAS + Ridging 50 DAS	85.6	82.3	94.1	90.2	84.8	83.7	73.3
9	Paraquat 0.48 kg ha^{-1} 25 DAS	-	-	-	56.5	55.8	-	-
10	Paraquat 0.48 kg ha^{-1} 25 DAS + Hand weeding 50 DAS	-	-	-	85.9	79.6	-	-
11	Paraquat 0.48 kg ha^{-1} 6 WAS	-	-	-	74.6	64.6	-	-
12	Paraquat 0.48 kg ha^{-1} 8 WAS	-	-	-	77.4	65.4	-	-

DAS: Days after sowing
WAS: Weeks after sowing
-: Not tested

Table 5: Effect of weed control treatments on grain yield of pigeonpea

		Grain yield (kg ha^{-1})						
Sr. No.	Treatment	1998	1999	2000	2001	2002	2003	2004
1	Unweeded Control	755	720	811	1226	1388	978	750
2	One hand weeding 30 DAS	1222	1074	1066	-	-	-	-
3	Two hand weedings 30+50 DAS	1600	1706	1333	1777	1855	1421	1133
4	Pendimethlin 0.45 kg ha^{-1} (pre-emergence)	-	-	-	1511	15.2	1102	850
5	Pendimethlin 0.75 kg ha^{-1} (pre-emergence)	1466	1493	1144	1555	1696	1326	950
6	Pendimethlin 0.45 kg ha^{-1} (pre-emergence) + Hand weeding 30 DAS	1644	1693	1344	1780	1840	1385	1033
7	Pendimethlin 0.45 kg ha^{-1} (pre-emergence) + Ridging 50 DAS	1733	1760	1388	1844	1896	1410	1133
8	Pendimethlin 0.45 kg ha^{-1} (pre-emergence) + Hand weeding 30 DAS + Ridging 50 DAS	1766	1840	1533	1877	1942	1456	1216
9	Paraquat 0.48 kg ha^{-1} 25 DAS	-	-	-	1551	1408	-	-
10	Paraquat 0.48 kg ha^{-1} 25 DAS + Hand weeding 50 DAS	-	-	-	1795	1789	-	-
11	Paraquat 0.48 kg ha^{-1} 6 WAS	-	-	-	1617	1396	-	-
12	Paraquat 0.48 kg ha^{-1} 8 WAS	-	-	-	1506	1328	-	-
	C.D. 5%	254	286	193	154	188	232	164

DAS: Days after sowing
WAS: Weeks after sowing
-: Not tested

Observations Recorded: Dry matter of weeds was recorded at harvest on plot basis after sun-drying for about 7 days and then converted into kg ha^{-1}.

Weed control efficiency (WCE) was calculated using the following formula:

WCE (%) = [(Dry matter of weeds in unweeded control - Dry matter of weeds in treated plot) × 100] / Dry matter of weeds in unweeded control plot

Grain yield data were recorded on whole plot basis and then converted into kg ha^{-1}. In 2004, data on plant height, number of primary branches plant^{-1}, number of secondary branches plant^{-1} and number of pods plant^{-1} were recorded from five randomly selected plants. Seed weight of 100 randomly selected seeds was also recorded.

Statistical Analysis: All data were subjected to analysis of variance (ANOVA) as per the standard procedure. Whenever 'F' ratio was found significant, critical difference (CD) value was calculated at p = 0.05 to compare the treatment means.

RESULTS AND DISCUSSION

Weeds: The predominant weed flora present in the experimental site were broad leaf weeds such as *Trianthema portulacastrum, Euphorbia hirta, Digera arvensis* and *Commelina benghalensis,* grassy weeds such as *Eleusine aegyptiacum, Digitaria sanguinalis, Eragrostis tenella* and *Cynodon dactylon* and sedge *Cyperus rotundus*. Paraquat controlled all weed species whereas pendimethalin controlled all other weed species except *Commelina benghalensis* and *Cyperus rotundus.*

Unweeded control plot, as expected, recorded the highest dry matter of weeds, which was reduced drastically by all other treatments (Table 3). One hand weeding 30 DAS reduced dry matter of weeds to half of the unweeded control, which was further reduced in the case of two hand weedings 30+50 DAS. Pendimethalin was found to be effective in controlling weeds and the higher dose of 0.75 kg ha^{-1} was superior to 0.45 kg ha^{-1}. The weeds dry matter decreased further when pendimethalin 0.45 kg ha^{-1} was integrated with either hand weeding 30 DAS or hand weeding 30 DAS + ridging 50 DAS. In pigeonpea, effective weed control has been reported with integrated use of pendimethalin and hand weeding [6,9].

Post-emergence application of paraquat also controlled weeds effectively and the effect was greater when paraquat 0.48 kg ha^{-1} 25 DAS was integrated with hand weeding 50 DAS. In 2004, sole application of pendimethalin @ 0.45 or 0.75 kg ha^{-1} did not reduce weed dry matter much (Table 3), which was due to the predominance of *Commelina benghalensis* which was not controlled. In some years, weed dry matter was higher than in others, which could be due to variation in rainfall received (Table 1). Singh *et al.* [10] also reported higher weed infestation in pigeonpea in a highly rainfall year.

Two hand weedings, pendimethalin in integration with hand weeding or ridging or both and paraquat in integration with hand weeding resulted in high WCE (Table 4). Integration of pendimethalin with hand weeding 40 DAS is known to provide high WCE in pigeonpea [11]. One hand weeding 30 DAS had low WCE, as after the hand weeding weeds appeared again. Similarly, sole applications of pendimethalin had low WCE, as this herbicide was effective only for initial about 30-day period only and later on as the effect of herbicide diminished weeds appeared again. Paraquat 0.48 kg ha^{-1} 25 DAS also had recorded low WCE as after initial killing of weeds, they started to grow again.

Pigeonpea Yield: Integration of pendimethalin 0.45 kg ha^{-1} + hand weeding 30 DAS + ridging 50 DAS provided the highest grain yields of pigeonpea (Table 5) in all the years of study. The other high yield providing treatments were two hand weedings 30 + 50 DAS, integrated use of pedimethalin with hand weeding or ridging and integrated use of paraquat with hand weeding. Higher grain yields in all these treatments may be due to better weed control as reflected in lower weed dry matter (Table 3), higher WCE (Table 4) and better plant growth and yield attributes (Table 6). Two hand weedings as well as the integrated use of pendimethalin + hand weeding are known to provide high grain yields of pigeonpea [12,13]. Compared to two hand weedings treatment, the uncontrolled weeds caused 52.8, 57.7, 39.1, 31.0, 25.1, 31.1 and 33.8 per cent reduction in grain yield in 1998, 1999, 2000, 2001, 2002, 2003 and 2004, respectively. This variation in yield losses due to weeds in different years could be due to various reasons including differences in soil properties, infestation of weed species and climatic conditions including rainfall (Table 1).

One hand weeding provided lower grain yields than two hand weedings due to poor weed control as reflected in higher dry matter of weeds (Table 3) and lower WCE (Table 4). Lower grain yields in case of paraquat 0.48 kg ha^{-1} 25 DAS were due to the appearance of weeds again.

Table 6: Effect of weed control treatments on plant growth and yield attributes of pigeonpea

Treatment	Plant height (cm)	Primary branches plant^{-1}	Secondary branches plant^{-1}	Pods number plant^{-1}	100-seed weight (g)
Unweeded control	164.6	4.36	7.73	78.6	6.00
Two hand weedings 30 + 50 DAS	198.6	5.20	9.40	111.3	6.76
Pendimenthlin 0.45 kg ha^{-1}	184.3	4.13	9.13	89.3	6.73
Pendimethlin 0.75 kg ha^{-1}	181.3	4.40	10.13	92.6	6.63
Pendimethlin 0.45kg ha^{-1} + Hand weeding 30 DAS	202.0	4.90	10.06	110.6	6.03
Pendimethlin 0.45 kg ha^{-1} + Ridging 50 DAS	203.3	4.76	10.06	107.3	6.80
Pendimethlin 0.45 kg ha^{-1} + Hand weeding 30 DAS + Ridging 50 DAS	201.0	4.90	10.60	108.3	6.40
C.D. 5%	15.2	0.64	1.30	10.5	0.51

DAS: Days after sowing

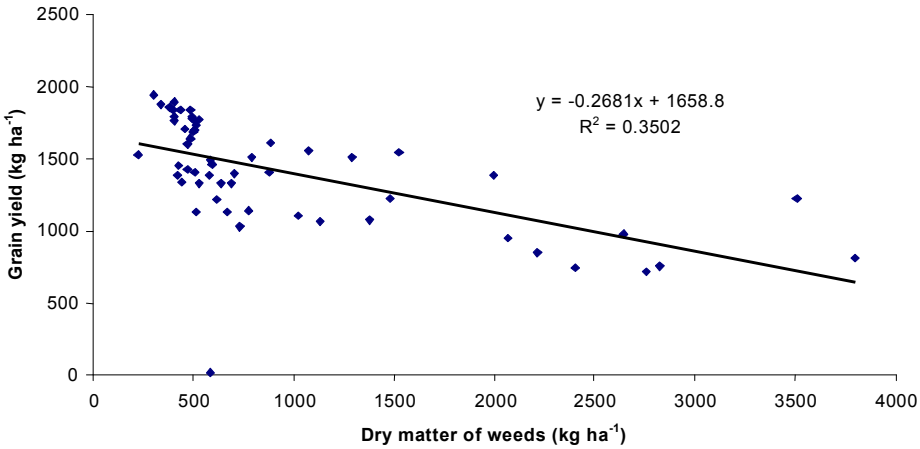

Fig. 1: Relationship between dry matter of weeds at harvest and grain yield of pigeonpea (1998-2004)

However, lower grain yields in case of paraquat 0.48 kg ha^{-1} 6 or 8 WAS was due to late control of weeds by which time weeds had already caused great losses due to their competition with crop plants for nutrients, moisture and/or light. As the dry matter of weeds increased, the grain yields of pigeonpea decreased (Fig. 1), thus emphasizing the need to control weeds for obtaining high grain yields.

From this study, it can be concluded that weed control is a limited factor for obtaining high grain yields of pigeonpea. Apart from two hand weedings 30+50 DAS, weeds can also be effectively controlled with integrated use of pendimethalin 0.45 kg ha^{-1} with hand weeding 30 DAS or ridging 50 DAS or both and integrated use of paraquat 0.48 kg ha^{-1} 25 DAS with hand weeding 50 DAS, which ultimately provide high grain yields of pigeonpea.

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