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Economic Analysis of Application of Weed Management Practices in *Kharif* and Summer Mungbean [*Vigna radiata* (L.) Wilczek]

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A B S T R A C T

This study investigates the economics of different weed management practices in *kharif* and summer mungbean [*Vigna radiata* (L.)Wilczek] under the Punjab (India) conditions. The field experiments (Experiment 1 and Experiment 2) were conducted during *kharif* 2016 and summer 2017 with ten different weed management treatments by replicating thrice in Randomized Complete Block Design (RCBD). Application of pendimethalin 30 ECat 0.45 kg ha^{-1} + hand weeding (HW) at 4 weeks after sowing (WAS) and pendimethalin 30 EC + imazethapyr 2 SL (pre-mix) at 0.45 kg ha^{-1} + HW at 4 WAS recorded statistically similar net returns with two HW at 4 and 6 WAS during both the seasons. Application of pendimethalin 30 EC at 0.45 kg ha^{-1} + HW at 4 WAS, pendimethalin 30EC at 0.75 kg ha^{-1} and imazethapyr 10 SL at 75 g ha^{-1} at 15 days after sowing (DAS) recorded higher, though statistically similar, B:C ratio than with two HW at 4 and 6 WAS. Pendimethalin 30 EC at 0.45 kg ha^{-1} + HW at 4 WAS, pendimethalin 30 EC at 0.75 kg ha^{-1}, pendimethalin 30 EC + imazethapyr 2 SL at 0.45 kg ha^{-1} + HW at 4 WAS and imazethapyr 10 SL at 75 g ha^{-1} at 15 DAS can act as alternative to two HW where labouris costly or not available at appropriate time for manual weeding in mungbean.

Introduction

Mungbean [*Vigna radiata* (L.) Wilczek] is the third most important pulse crop in India (Tiwari and Shivhare 2016).Mungbean contains 22-28% protein, 60-65% carbohydrates, 1-1.5% fat, 3.5-4.5% fibre and 4.5-5.5% ash (Anonymous, 2017). Due to its short duration and being adaptable to be grown during both the summer and the *kharif* season, mungbean is a good potential crop to be used under intensive cropping systems. In addition to providing additional income to the farmers, it also provides sustainability to the agriculture system by enriching soil with nitrogen through biological nitrogen fixation (BNF) process.

Weed management is very important aspect for obtaining higher productivity of the crop. Uncontrolled weed flora reduced grain yield in mungbean by47-76% (Singh *et al.*, 2015), in mash [*Vigna mungo* L. Hepper] by 38% (Aggarwal *et al.*, 2014) and in soybean [*Glycine max* L. Merrill] by 40-51% (Ram *et al.*, 2013). Weeds can be effectively controlled by hand weeding (Sekhon *et al.*, 1996; Singh *et al.*, 2002; Singh *et al.*, 2010). However, decrease in labour availability and increased cost of cultivation are the major bottleneck for manual removal of weeds by hand weeding. The usage of herbicides in Indian agriculture is increasing due to high yield losses by weeds, decreasing labour availability and increasing knowledge about their use among the farmers. Thus, it becomes even more important to find out economically viable herbicide treatments which can substitute the traditional manual hand weeding practices, increasing the profit to farmers and reducing the drudgery of human labour.

Herbicides have shown promising results in controlling weeds and improving grain yield of various pulses (Kaur *et al.*, 2009; Singh, 2011; Singh and Sekhon, 2013; Singh *et al.*, 2014a; Singh *et al.*, 2016). Ram *et al.*, (2012) studied the effect of imazethapyr in French bean (*Phaseolus vulgaris* L.) and observed that application of imazethapyr at 50 g ha^{-1} 20 DAS significantly reduced the plant height, branches $plant^{-1}$, and grains pod^{-1} as compared to two HW at 20 and 40 DAS. However, grain yield and grain index remained at par with two HW treatment. Application of imazethapyr 10 SL at 75 or 100 g ha^{-1} at either 15 or 25 DAS in soybean recorded higher net income and benefit cost ratio as compared with that in two HW treatment (Ram *et al.*, 2013). In groundnut (*Arachis hypogea* L.) application of pendimethalin at 1.0 kg ha^{-1} + HW at 45 DAS increased pod yield as compared to that in two HW at 20 and 35 DAS Kumar *et al.*, (2013). In chickpea (*Cicerarietinum* L.) pendimethalin at 1.0 kg ha^{-1} recorded grain yield and straw yield statistically similar with two hoeing + HW at 30 DAS Bhutada and Bhale (2015). Patel *et al.*,(2016) reported that application of pendimethalin + imazethapyr at 0.75 kg ha^{-1} and 1.0 kg ha^{-1} recorded statistically at par grain yield to that in HW twice in field pea (*Pisum sativum* L.). Higher benefit cost ratio was recorded in pendimethalin at 1.0 kg ha^{-1} than HW twice, which might be due to reduced cost of HW. Reduction in weed competition, high grain yield and low input cost of herbicides result in high net returns. Problem of timely and low cost availability of human labour for hand weeding could also be solved by using economical herbicides.

In mungbean, pendimethalin, imazethapyr and pendimethalin + imazethapyr (pre-mix) are the promising herbicides. Pendimethalin is an herbicide of the di-nitroaniline class, used for control of annual grasses and certain broadleaf weeds. It inhibits cell division and cell elongation. Imazethapyr is an imidazolinone herbicide that effectively controls a broad spectrum of weed species. These herbicides kill plants by inhibiting acetohydroxy acid synthase (AHAS). Use of pendimethalin, imazethapyr and pendimethalin + imazethapyr in mungbean may be found effective in increasing monetary benefits to farmers by reducing the labour requirement thus lowering cost of production and lowering the drudgery of farmer and his family. Therefore, these herbicides were tested in *kharif* as well as summer mungbean.

Materials and Methods

The present study was conducted in two experiments *i.e.*, Experiment 1 (*kharif* 2016) and Experiment 2 (summer 2017) at research farm of Pulses Section, Department of Plant Breeding and Genetics, Department, Punjab Agricultural University, Ludhiana. The soil of Experiment 1 had medium organic carbon (0.61%), low available nitrogen content (144 kg ha^{-1}), high available phosphorus (28.5 kg ha^{-1}) and medium available potassium (161 kg ha^{-1}). The soil of Experiment 2 was low in organic carbon (0.36%) and had low available nitrogen content (130 kg ha^{-1}), medium available phosphorus (16.2 kg ha^{-1}) and medium available potassium (158 kg ha^{-1}). Both the experiments were laid out in Randomized Complete Block Design (RCBD) replicated three times with ten treatments (*viz.* pendimethalin 30 EC at 0.45 kg ha^{-1}pre-emergence (PE) + HW at 4 WAS, pendimethalin 30 EC at 0.75 kg ha^{-1} (PE), pendimethalin 30 EC + imazethapyr 2 SL at 0.45 kg ha^{-1}(PE) + HW at 4 WAS, pendimethalin 30 EC + imazethapyr 2 SL at 0.75 kg ha^{-1} (PE), imazethapyr 10 SL at 50 g ha^{-1} at 15 or 25 DAS, imazethapyr 10 SL at 75 g ha^{-1} at 15 or 25 DAS, two HW at 4 & 6 WAS and weedy check).

Applications of herbicides were done by using water at 500 L ha^{-1}. Pre-emergence herbicides were applied in the evening on the day of sowing of crop. Post-emergence herbicides treatments were also applied in the evening at 15 and 25 DAS as per the treatments.

The sowing of mungbean in Experiment 1 (cultivar ML 2056) was done on 20^{th} July, 2016 at a row spacing of 30 cm using a seed rate of 20 kg ha^{-1}. Mungbean in Experiment 2 (cultivar SML 832) was sown on 28^{th} March, 2017 at a row spacing of 22.5 cm using a seed rate of 30 kg ha^{-1}. Whole amount of nitrogen at the rate of 12.5 kg ha^{-1} and phosphorus at the rate of 40 kg ha^{-1} was applied at the time of sowing in both experiments. Experiment 1 was harvested on 8 October, 2016 while, Experiment 2 was harvested on 8 June, 2017. The crop was raised as per the recommendations (PAU 2016, PAU 2017).

Total variable costs

For calculating total variable costs, the total costs of cultivation (*i.e.* total variable costs) were taken into account for both the experiments. Cost of cultivation varied with the treatments applied. The cost of cultivation included money spends on seed, fertilizers, seed inoculation, weed management practices, human labour, insecticides, irrigation etc. The details of all the costs involved in different inputs used in Experiments 1 and 2 are presented in Tables 1 and 2, respectively. It was expressed as Rs ha^{-1}.

Gross returns

For calculating gross returns, the grain yield was multiplied by minimum support price (MSP) and the stover yield was multiplied with prevalent market price. This was denoted in Rs ha^{-1}. Gross returns calculated for the Experiment 1 and Experiment 2 are presented in Tables 3 and 4. The formula implied for calculations is given below.

Gross returns = [Grain yield (kg ha^{-1}) × Rs 52.25 kg^{-1}] + [Stover yield (kg ha^{-1}) × Rs 1.20 kg^{-1}]

Net returns

Net returns were calculated by subtracting total variable costs from the gross returns. It was expressed as Rs ha^{-1}.

Net returns = Gross returns – Total variable costs

Benefit cost ratio

The benefit cost ratio was calculated by dividing the net returns with the variable costs.

Benefit cost ratio= Net returns ÷ Total variable costs

Results and Discussion

Total variable costs

The highest total variable cost in both the experiments was recorded in two HW at 4 and 6 WAS followed by pendimethalin 30 EC + imazethapyr 2 SL at 0.45 kg ha^{-1} + HW at 4 WAS and pendimethalin 30 EC at 0.45 kg ha^{-1} + HW at 4 WAS (Tables 3 and 4). The lowest total variable costs were recorded in weedy check. Application of post-emergence applications of imazethapyr 10 SL recorded lower total variable costs as compared to pre-emergence herbicide treatments. Two HW treatment recorded in 32.4 and 33.3% higher total variable costs as compared with weedy check in Experiment1 and Experiment 2, respectively. Application of imazethapyr 10 SL at 50 g ha^{-1} at 15 and 25 DAS recorded lowest increase in total variable costs (1.79 and 1.81% in Experiment 1 and Experiment 2, respectively) as compared to weedy check.

Gross returns

In Experiment 1, the highest gross returns were recorded in two HW treatment, which were statistically at par with that in pendimethalin 30 EC at 0.45 $kgha^{-1}$ + HW at 4 WAS and pendimethalin 30 EC + imazethapyr 2 SL at 0.45 $kgha^{-1}$ + HW at 4 WAS (Table 3).

In Experiment 2, application of pendimethalin 30 EC at 0.45 kg ha^{-1} + HW at 4 WAS recorded statistically similar gross returns with that in two HW treatment (Table 4). Application of other herbicide treatments recorded significantly lower gross returns as compared to that in two HW treatment.

Higher gross returns recorded in these treatments could be due to higher grain and stover yield. Weedy check reduced gross returns by 51.31 and 48.25% as compared to two HW at 4 and 6 WAS treatment in Experiment 1 and Experiment 2, respectively. Similar results for pendimethalin and imazethapyr were recorded by Singh *et al.*, (2015) and pendimethalin + imazethapyr by Lhungdim *et al.*, (2013).

In both experiments, among the post-emergence herbicide treatments, application of imazethapyr 10 SL at 75 g ha^{-1} at 15 DAS recorded highest gross returns followed by that in imazethapyr 10 SL at 50 g ha^{-1} at 15 DAS (Tables 3 and 4). Applications of imazethapyr 10 SL at 50 and 75 g ha^{-1} at 15 DAS recorded higher gross returns as compared to that in imazethapyr 10 SL at 50 and 75 g ha^{-1} at 25 DAS as also recorded by Singh *et al.*,(2014b).The lowest gross returns were recorded in weedy check, in both *kharif* and summer mungbean (Tables 3 and 4).

Net returns

In Experiment 1, the highest net returns were recorded in two HW at 4 and 6 WAS treatment, which were statistically at par with that in pendimethalin 30 EC at 0.45 $kgha^{-1}$ + HW at 4 WAS and pendimethalin 30 EC + imazethapyr 2 SL at 0.45 $kgha^{-1}$ + HW at 4 WAS (Table 3). Application of pendimethalin 30 EC at 0.75 kg ha^{-1} and imazethapyr 10 SL at 75 g ha^{-1} at 25 DAS recorded high net returns. Weedy check recorded the lowest net returns, reducing 68.67% as compared to two HW at 4 and 6 WAS.

In Experiment 2, application of pendimethalin 30 EC at 0.45 $kgha^{-1}$ + HW at 4 WAS, pendimethalin 30 EC at 0.75 kg ha^{-1}, pendimethalin 30 EC + imazethapyr 2 SL at 0.45 $kgha^{-1}$ + HW at 4 WAS and imazethapyr 10 SL at 75 g ha^{-1} at 15 DAS recorded statistically at par net returns with that in two HW treatment (Table 4). High net returns recorded in these treatments could be due to higher grain yield and stover yield and lower total costs by usage of herbicides. Weedy check resulted in the maximum reduction (68.46%) in net returns. Application of imazethapyr 10 SL at 50 g ha^{-1} at 15 DAS and imazethapyr at 75 g ha^{-1} at 15 DAS recorded higher net returns as compared to that in imazethapyr 10 SL at 50 g ha^{-1} at 15 DAS and imazethapyr at 75 g ha^{-1} at 25 DAS, in both experiments. Lowest net returns were recorded in weedy check (Tables 3 and 4). Similar findings for pendimethalin, imazethapyr and pendimethalin + imazethapyr were also reported by Chandrakar *et al.*, (2014).

Table.1 Price of produce and inputs used to calculate the economics in Experiment 1

Particulars	Item	Quantity (ha^{-1})	Price $unit^{-1}$ (Rs)	Total (Rs)
Returns				
	Grain yield		52.25 kg^{-1}	
	Stover yield		1.20 kg^{-1}	
Variable Costs				
Seed and seed treatment	Seed	20 kg	110 kg^{-1}	2200
	Seed treatment	60 g	600 kg^{-1}	36
	Seed inoculation	2.5 packets	20	50
Fertilizers	Urea	27 kg	544 q^{-1}	150
	SSP	250 kg	660 q^{-1}	1650
Plant Protection	Ekalux	4 L (2 L + 2 L)	536 L^{-1}	2144
	Indoxacarb	500 ml	2200 L^{-1}	1100
	Triazophos	1.5 L	420 L^{-1}	630
Miscellaneous	Irrigation	2	60	120
	Human Labour	425 hours	40	17000
	Tractor hours	7.5 hours	360	2700
Treatment cost				
Pendimethalin 30 EC at 0.45 kg ha^{-1} (PE) + HW at 4 WAS		1.5 L + 1 + 15	675+5250	5925
Pendimethalin 30 EC at 0.75 kg ha^{-1} (PE)		2.5 L + 1	1125+750	1875
Pendimethalin 30 EC + imazethapyr 2 SL at 0.45 kg ha^{-1} (PE) + HW at 4 WAS		1.4 L + 1 + 15	625+5250	5875
Pendimethalin 30 EC + imazethapyr 2 SL at 0.75 kg ha^{-1} (PE)		2.4 L + 1	1776+750	2526
Imazethapyr 10 SL at 50 g ha^{-1} at 15 DAS		500 ml + 1	500+750	1250
Imazethapyr 10 SL at 50 g ha^{-1} at 25 DAS		500 ml + 1	500+750	1250
Imazethapyr 10 SL at 75 g ha^{-1} at 15 DAS		750 ml + 1	750+750	1500
Imazethapyr 10 SL at 75 g ha^{-1} at 25 DAS		750 ml + 1	750+750	1500
Two hand weedings at 4 and 6 WAS		0 + 30	9000	9000
Weedy check		0	0	0

Table.2 Price of produce and inputs used to calculate the economics in Experiment 2

Particulars	Item	Quantity (ha^{-1})	Price unit^{-1} (Rs)	Total (Rs)
Returns				
	Grain yield		52.25 kg^{-1}	
	Stover yield		1.20 kg^{-1}	
Variable Costs				
Seed and seed treatment	Seed	30 kg	110 kg^{-1}	3300
	Seed treatment	90 g	600 kg^{-1}	54
	Seed inoculation	5 packets	20	100
Fertilizers	Urea	27 kg	544 q^{-1}	150
	SSP	250 kg	660 q^{-1}	1650
Plant Protection	Ekalux	2 L (1 L + 1 L)	536 L^{-1}	1072
	Indoxacarb	1 L	2200 L^{-1}	2200
	Triazophos	1.5 L	420 L^{-1}	630
	Dimethoate	250 ml	330 L^{-1}	85
Miscellaneous	Irrigation	5	60	300
	Human Labour	370 hours	40	14800
	Tractor hours	7.5 hours	360	2700
Treatment cost				
Pendimethalin 30 EC at 0.45 kg ha^{-1} (PE) + HW at 4 WAS		1.5 L + 1 + 15	675+5250	5925
Pendimethalin 30 EC at 0.75 kg ha^{-1} (PE)		2.5 L + 1	1125+750	1875
Pendimethalin 30 EC + imazethapyr 2 SL at 0.45 kg ha^{-1} (PE) + HW at 4 WAS		1.4 L + 1 + 15	625+5250	5875
Pendimethalin 30 EC + imazethapyr 2 SL at 0.75 kg ha^{-1} (PE)		2.4 L + 1	1776+750	2526
Imazethapyr 10 SL at 50 g ha^{-1} at 15 DAS		500 ml + 1	500+750	1250
Imazethapyr 10 SL at 50 g ha^{-1} at 25 DAS		500 ml + 1	500+750	1250
Imazethapyr 10 SL at 75 g ha^{-1} at 15 DAS		750 ml + 1	750+750	1500
Imazethapyr 10 SL at 75 g ha^{-1} at 25 DAS		750 ml + 1	750+750	1500
Two hand weedings at 4 and 6 WAS		0 + 30	9000	9000
Weedy check		0	0	0

Table.3 Effect of herbicide treatments on economic analysis in Experiment 1

Treatment	Total variable costs (Rs ha^{-1})	Returns (Rs ha^{-1})		B:C
		Gross	Net	
Pendimethalin 30 EC at 0.45 kg ha^{-1} (PE) + HW at 4 WAS	32955	88618	55663	1.69
Pendimethalin 30 EC at 0.75 kg ha^{-1} (PE)	28905	76663	47758	1.65
Pendimethalin 30 EC + imazethapyr 2 SL at 0.45 kg ha^{-1} (PE) + HW at 4 WAS	33345	85737	52392	1.57
Pendimethalin 30 EC + imazethapyr 2 SL at 0.75 kg ha^{-1} (PE)	29556	69529	39973	1.35
Imazethapyr 10 SL at 50 g ha^{-1} at 15 DAS	28280	68525	40275	1.42
Imazethapyr 10 SL at 50 g ha^{-1} at 25 DAS	28280	61267	32987	1.17
Imazethapyr 10 SL at 75 g ha^{-1} at 15 DAS	28530	74187	45657	1.60
Imazethapyr 10 SL at 75 g ha^{-1} at 25 DAS	28530	56703	28173	0.99
Two hand weedings at 4 and 6 WAS	36780	93633	56853	1.55
Weedy check	27780	45588	17808	0.64
CD (p=0.05)		9093	9093	0.30

Table.4 Effect of herbicide treatments on economic analysis in Experiment 2

Treatment	Total variable costs (Rs ha^{-1})	Returns (Rs ha^{-1})		B:C
		Gross	Net	
Pendimethalin 30 EC at 0.45 kg ha^{-1} (PE) + HW at 4 WAS	32166	70762	38596	1.20
Pendimethalin 30 EC at 0.75 kg ha^{-1} (PE)	28116	61952	33836	1.20
Pendimethalin 30 EC + imazethapyr 2 SL at 0.45 kg ha^{-1} (PE) + HW at 4 WAS	32556	66855	34299	1.05
Pendimethalin 30 EC + imazethapyr 2 SL at 0.75 kg ha^{-1} (PE)	28767	61060	32293	1.12
Imazethapyr 10 SL at 50 g ha^{-1} at 15 DAS	27491	58618	31127	1.13
Imazethapyr 10 SL at 50 g ha^{-1} at 25 DAS	27491	51850	24359	0.89
Imazethapyr 10 SL at 75 g ha^{-1} at 15 DAS	27741	63942	36201	1.31
Imazethapyr 10 SL at 75 g ha^{-1} at 25 DAS	27741	49062	21321	0.77
Two hand weedings at 4 and 6 WAS	35991	77374	41383	1.15
Weedy check	26991	40044	13053	0.48
CD (p=0.05)		7940	7940	0.28

Benefit cost ratio

A benefit cost ratio helps to realize the relationship between the costs and benefits involved in a system. If the value of benefit cost ratio is higher than 1, it indicates the net profit involved. Value less than 1 of benefit cost ratio indicates net losses. General thumb rule is that if the benefit is higher than the cost involved in the project, it can be considered as good investment.

In Experiment 1, application of pendimethalin 30 EC at 0.45 kg ha^{-1} + HW at 4 WAS recorded maximum benefit cost ratio, however, all the herbicide treatments except imazethapyr 10 SL at 50 and 75 g ha^{-1} at 25 DAS recorded benefit cost ratio statistically at par with that in two HW (Table 3). In Experiment 2, the highest benefit cost ratio was observed in imazethapyr 10 SL at 75 g ha^{-1} at 15 DAS. Application of all the herbicide treatments except imazethapyr 10 SL at 75 g ha^{-1} at 25 DAS recorded statistically similar benefit cost ratio with that in two HW. The lowest benefit cost ratio was observed in weedy check in both experiments. Results are in line with the findings of Khairnar *et al.*, (2014) and Balyan *et al.*, (2016).

It can be concluded that application of HW recorded highest gross (Rs 93633 in Experiment 1 and Rs 77374 in Experiment 2) and net returns (Rs 56863 during Experiment 1and Rs 41383 in Experiment 2). Application of pendimethalin 30 EC at 0.45 kg ha^{-1} + HW at 4 WAS (1.69) and imazethapyr 10 SL at 75 g ha^{-1} at 15 DAS (1.31) recorded highest benefit cost ratio in Experiment 1 and Experiment 2, respectively. Therefore, it can be concluded that HW twice is recommended for higher returns, however, pendimethalin 30 EC at 0.45 kg ha^{-1} + HW at 4 WAS, pendimethalin 30 EC at 0.75 kg ha^{-1}, pendimethalin 30 EC + imazethapyr 2 SL at 0.45 kg ha^{-1} + HW at 4 WAS and imazethapyr 10 SL at 75 g ha^{-1} at 15 DAS can act as alternative where labour was costly or not available at appropriate time for manual weeding in mungbean.

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