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Effect of integrated weed management practices on weed control efficiency, yield and economics in brinjal

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Abstract
An experiment was conducted on the effect of different integrated weed management practices on weed control efficiency, yield and economic analysis in brinjal at Vegetable Research Station, Agriculture Research Institute, Rajendranagar, Hyderabad. The experiment was laid out in randomized block design with thirteen treatment combinations and replicated thrice. Among the treatments, the highest number of fruits per plant (28.46), highest average fruit weight (45.33 g) and highest fruit yield (31.10 t ha^{-1}) was noticed with hand weeding three times at 20, 40 and 60 days after transplanting and also the highest gross returns (Rs.3,73,200), cost of cultivation (Rs. 66,800) and net returns (Rs. 3,06,400) followed by inter cultivation at 25 and 50 DAT (T_{11}). The highest weed control efficiency was recorded at 30 DAT in the treatment glyphosate @ 1.5 kg a.i ha^{-1} directed spray at 25 and 50 DAT (T_{10}) (87.23%). At 60 DAT highest weed control efficiency was recorded in pendimethalin C.S as pre-emergence @ 0.70 kg a.i ha^{-1} + one hand weeding at 45 DAT (T_1) (92.98%) whereas at 90 DAT and at final harvesting stage highest weed control efficiency was recorded in the treatment hand weeding three times at 20, 40 and 60 DAT (T_{12}) (81.06% and 79.89% respectively). Minimum weed index was recorded in the treatment inter cultivation at 25 and 50 DAT (T_{11}) (15.80%).

Keywords: Brinjal, BC ratio, integrated weed management, weed control efficiency, weed index.

Introduction
Brinjal (*Solanum melongena* L.) is an important commercial vegetable crop. It belongs to the family solanaceae. Brinjal is also variously known as Eggplant or Aubergine (French name). It is one of the most common, popular and principal vegetable crops grown in India and other parts of world. It is also popular in France, Italy and United states. India is regarded as the centre of origin of brinjal crop (Vavilov, 1931; Bhaduri, 1951) [10, 1]. In India it is grown in an area of 589.5 thousand hectares, producing 10,163.1 thousand tonnes with a productivity of 17,240 kg ha^{-1}. West Bengal (2,797.3 thousand tonnes) Orissa (2,135.2 thousand tonnes) Bihar (1,198 thousand tonnes) Andhra Pradesh (485.0 thousand tonnes) followed by Karnataka (372.70 thousand tonnes) and Uttar Pradesh (90.9 thousand tonnes) are the major producing states in India. In Andhra Pradesh it is grown in an area of 24.30 thousand hectares, producing 485.50 thousand tonnes and the productivity is 19,959 kg ha^{-1} (CMIE-2010) [2]. Weeds pose the most serious problem in brinjal cultivation because of liberal use of farmyard manure, chemical fertilizers and frequent irrigations that help the weeds to grow vigorously. It has been well established that losses from weeds accounts for 45 per cent more when compared to insect pest and diseases which accounts for 30 and 20 per cent, respectively (Rao, 1993) [7]. In most of the vegetables crops, the early growth period is the most critical stage at which stresses of any kind affects the economic yields. Weed competition is the important stress during this period. Besides, this period coincides with the season of peak labour activity leading to scarcity of labour for weeding which adds additional cost to production. Therefore, it is the prime need to adopt integrated weed management practices to obtain maximum productivity. The herbicides when used in combination with one or two hand weedings, improves their efficiency and the pre-emergent herbicides are beneficial to keeps the crop weed free in the early stages. During later stages, hand weeding helps to reduce the cost of weeding and keeps the weed population below the economic threshold level throughout the crop growth period. Keeping all this in view, the present investigation was carried out to study the effect of different integrated weed management practices on weed control efficiency, yield and economic analysis in brinjal at Vegetable Research Station, Agriculture Research Institute, Rajendranagar, Hyderabad, during *kharif* season.

Materials and methods

The field experiment was conducted at Vegetable Research Station, Agriculture Research Institute, Rajendranagar, Hyderabad, during *kharif* 2011. The experimental site comes under sub-tropical zone and is situated at a latitude of 17^0 19^1 N, longitude of 79^0 23^1 E and an altitude of 546.2 m above mean sea level. The mean annual precipitation on the basis of last ten years is 852 mm which received mostly from South-West Monsoon during June to October. The mean annual minimum and maximum temperatures are 20.2ºC and 32.6ºC respectively. The humidity ranged from 44.5 per cent in summer and 79.4 per cent in rainy season. thus the site has hot dry summer and moderate cold winter.

Thirty days old seedlings were transplanted in the main field at a spacing of 60 cm × 50 cm. Different herbicides with thirteen treatment combinations *viz.*, T_1- Pendimethalin C.S as pre-emergence @ 0.70 kg a.i ha^{-1} + one hand weeding at 45 DAT, T_2- Oxadiargyl as pre-emergence @ 90 g a.i ha^{-1} + one hand weeding at 45 DAT, T_3- Oxyfluorfen as pre-emergence @ 0.15 kg a.i ha^{-1} + one hand weeding at 45 DAT, T_4- Pendimethalin C.S as pre-emergence @ 0.70 kg a.i ha^{-1} followed by quizalofop ethyl @ 50 g a.i ha^{-1} at 15 to 20 DAT, T_5- Oxadiargyl as pre-emergence @ 90 g a.i ha^{-1} followed by quizalofop ethyl @ 50 g a.i ha^{-1} at 15 to 20 DAT, T_6- Oxyfluorfen as pre-emergence @ 0.15 kg a.i ha^{-1} followed by quizalofop ethyl @ 50 g a.i ha^{-1} at 15 to 20 DAT, T_7- Pendimethalin C.S as pre-emergence @ 0.70 kg a.i ha^{-1} followed by propaquiza fop @ 62.5 g a.i ha^{-1} at 15 to 20 DAT, T_8-Oxadiargyl as pre-emergence @ 90 g a.i ha^{-1} followed by propaquiza fop @ 62.5 g a.i ha^{-1} at 15 to 20 DAT, T_9- Oxyfluorfen as pre emergence @ 0.15 kg a.i ha^{-1} followed by propaquiza fop @ 62.5 g a.i ha^{-1} at 15 to 20 DAT, T_{10}- Glyphosate @ 1.5 kg a.i ha^{-1}directed spray at 25 and 50 DAT, T_{11}- Inter cultivation at 25 and 50 DAT, T_{12}- Hand weeding three times at 20, 40 and 60 DAT. and T_{13}- Control were tried and replicated thrice.

The required amount of herbicides for the experimentation was calculated by using the following formula.

$$\text{Commercial herbicide} = \frac{RA}{C} \times 100$$

Here, R = Recommended dose of herbicide per hectare
A = Area (hectares)
C = Concentration of herbicide

Thus calculated amount of herbicide was sprayed in each treatmental plot using knapsack sprayer with flat pan nozzle with a spray volume of 600 litre of water per hectare. The quantity of herbicide per plot (4.2 m x 4 m) was calculated by using above formula and dissolved in water and spread over an area of 16.8 m^2 according to different treatments.

The weed control efficiency (WCE) was calculated by the following formula suggested by Patil and Patil (1993) [6] and expressed in percentage. The weed control efficiency was derived at 30, 60, 90 DAT and at harvest and expressed in percentage.

$$WCE = \frac{DMC - DMT}{DMC} \times 100$$

Where, DMC= dry matter of weed in control plot
DMT= dry matter of weed in treatment plot
WCE=weed control efficiency

The weed index (WI) is defined as the reduction in yield due to the presence of weeds in comparison with no weed plot was worked out for each plot with the formula suggested by Gill and Vijay Kumar (1966) [3] and expressed in percentage.

$$WI = \frac{X - Y}{X} \times 100$$

Where, X = brinjal yield from minimum weed competition plot
Y = brinjal yield from the treated plot
WI= Weed index.

Average fruit number per plant was taken as the total number of fruits in each treatment divided by the total plants in each treatment. Average fruit weight was taken as total weight of the fruits in each treatment divided by total number of fruits in each treatment. The marketable yield per hectare of brinjal fruits was computed and recorded accordingly in tonnes per hectare.

By presuming the item wise input cost on the basis of local market rate, the cost of cultivation per hectare was worked out and it was computed treatment wise also.

From the total yield of each treatment plot, the gross monetary returns was worked out on the basis of average selling price of the produce and it was recorded accordingly in Rs. ha^{-1}.

From the gross monetary return of each treatment plot, the expenditure incurred on the same treatment was deducted and treatment wise net monetary returns was worked out and recorded accordingly in Rs. ha^{-1}.

From the net monetary return of each treatment plot, the net monetary return of the control was deducted and net profit over control treatment was worked out and recorded accordingly as net profit over control treatment in Rs. ha^{-1}.

From the values of net monetary return of each treatment plot and expenditure incurred on the same treatment, cost benefit ratio was worked out and recorded accordingly. Benefit: Cost ratio was worked out by using the formula given below.

$$\text{B: C ratio} = \frac{\text{Net returns (Rs. ha}^{-1})}{\text{Cost of cultivation (Rs ha}^{-1})}$$

Results and discussion

Among all the different treatments, the highest weed control efficiency was recorded at 30 DAT in the treatment glyphosate @ 1.5 kg a.i ha^{-1} directed spray at 25 and 50 DAT (T_{10}) (87.23%). At 60 DAT highest weed control efficiency was recorded in pendimethalin C.S as pre-emergence @ 0.70 kg a.i ha^{-1} + one hand weeding at 45 DAT (T_1) (92.98%) whereas at 90 DAT and at final harvesting stage highest weed control efficiency was recorded in the treatment hand weeding three times at 20, 40 and 60 DAT (T_{12}) (81.06% and 79.89% respectively. Similar results have been obtained by Nadagouda (1995) [4] and Nekar (1997) [5].

Regarding weed index, minimum value was recorded in the treatment inter cultivation at 25 and 50 DAT (T_{11}) (15.80%) followed by pendimethalin C.S as pre-emergence @ 0.70 kg a.i ha^{-1} + one hand weeding at 45 DAT (T_1) (16.89%) and oxadiargyl as pre-emergence @ 90 g a.i ha^{-1} + one hand weeding at 45 DAT (T_2) (20.74%) and oxyfluorfen as pre-emergence @ 0.15 kg a.i ha^{-1} + one hand weeding at 45 DAT (T_3) (20.94%), whereas the highest weed index was recorded in the treatment glyphosate @ 1.5 kg a.i ha^{-1} directed spray at 25 and 50 DAT (T_{10}) (72.06%) followed by control (T_{13})

(70.25%). This clearly indicates that inter cultivation at 25 and 50 days after transplanting and application of pendimethalin @ 0.70 kg a.i. ha^{-1} was very effective in controlling weeds and thus resulted in significantly lower values for weed index (WI), which is an ideal parameter to judge the effectiveness of herbicides. These results are in confirmity with the results reported by Shivalingappa *et al*., (2014) [9].

With respect to yield attributes, significantly the highest number of fruits per plant was recorded in hand weeding three times at 20, 40 and 60 DAT (T_{12}) (28.46), whereas the lowest number of fruits was recorded in control (T_{13}) (21.69). The highest average fruit weight was recorded in hand weeding three times at 20, 40 and 60 DAT (T_{12}),(45.33 g fruit^{-1}) whereas the lowest average fruit weight was recorded in glyphosate @ 1.5 kg a.i ha^{-1} directed spray at 25 and 50 DAT (T_{10}) (26.33) followed by control (T_{13}) (28.33 g fruit^{-1}) (Table 2).

Different integrated weed management practices did exhibit significant effect on marketable yield**, (**Table 2). Among all the treatments, significantly the highest fruit yield was recorded in hand weeding three times at 20, 40 and 60 DAT (T_{12}) (31.10 t ha^{-1}) whereas the lowest yield was recorded in glyphosate @ 1.5 kg a.i ha^{-1} directed spray at 25 and 50 DAT (T_{10}) (9.72 t ha^{-1}) followed by control (T_{13}) (10.13 t ha^{-1}).

The highest cost of cultivation was recorded in hand weeding three times at 20, 40 and 60 DAT (T_{12}) (Rs. 66,800.00 ha^{-1}) followed by inter cultivation 25 and 50 DAT (Rs. 49,820.00 ha^{-1}) and pendimethalin C.S as pre-emergence @ 0.70 kg a.i ha^{-1} + one hand weeding at 45 DAT (T_1) (Rs. 50,180.00 ha^{-1}) whereas the lowest cost of cultivation was recorded in control (T_{13}) (Rs. 45,800.00 ha^{-1}).

With respect to gross returns, the highest gross returns was recorded in hand weeding three times at 20, 40 and 60 DAT (T_{12}) (Rs. 3,73,200.00 ha^{-1}.) compared to other treatments, followed by intercultivation 25 and 50 DAT (T_{11}) (Rs. 3,47,040.00 ha^{-1}) and pendimethalin C.S as pre-emergence @ 0.70 kg a.i ha^{-1} + one hand weeding at 45 DAT (T_1) (Rs. 3,38,520.00 ha^{-1}) whereas glyphosate @ 1.5 kg a.i ha^{-1} directed spray at 25 and 50 DAT (T_{10}) recorded the lowest gross returns (Rs. 1,16,640.00 ha^{-1}) followed by control (T_{13}) (Rs.1,24,200.00 ha^{-1}).

The highest net returns was recorded in hand weeding three times at 20, 40 and 60 DAT (T_{12}) (Rs. 3,06,400.00 ha^{-1}), whereas the lowest net returns was recorded in glyphosate @ 1.5 kg a.i ha^{-1} directed spray at 25 and 50 DAT (T_{10}) (Rs. 68,937.00ha^{-1}) followed by control (T_{13}) (Rs. 78,400.00 ha^{-1}).

The highest B:C ratio was recorded in intercultivation at 25 and 50 DAT (T_{11}) (5.96) followed by pendimethalin C.S as pre-emergence @ 0.70 kg a.i ha^{-1} + one hand weeding at 45 DAT (T_1) (5.75), oxadiargyl as pre-emergence @ 90 g a.i ha^{-1} + one hand weeding at 45 DAT (T_2) (5.58) and oxyfluorfen as pre-emergence @ 0.15 kg a.i ha^{-1} + one hand weeding at 45 DAT (T_3) (5.56) whereas the lowest B:C ratio was recorded in glyphosate @1.5 kg a.i ha^{-1} directed spray at 25 and 50 DAT (T_{10}) (1.44) followed by control (T_{13}) (1.71).

Among the different integrated weed management practices, the treatment hand weeding three times at 20, 40 and 60 DAT (T_{12}) recorded the highest average fruit weight, number of fruits per plant and in turn increased the marketable yield per hectare, followed by intercultivation at 25 and 50 DAT (T_{11}) followed by the treatment pendimethalin C.S as pre-emergence @ 0.70 kg a.i ha^{-1} + one hand weeding at 45 DAT (T_1) which was on par with oxadiargyl as pre-emergence @ 90 g a.i ha^{-1} + one hand weeding at 45 DAT (T_2) and oxyfluorfen pre-emergence @ 0.15 kg a.i ha^{-1} + one hand weeding at 45 DAT (T_3), which are incuncurrence with the findings of Reddy *et al.,* (2000) [8].

Table 1: Weed control efficiency (%) at different growth stages and weed index (%) as influenced by different weed management practices in brinjal.

Treatments	30 DAT	60 DAT	90 DAT	At harvest	Weed index (%)
T_1 - Pendimethalin C.S as pre- emergence @ 0.70 kg a.i ha^{-1} + one hand weeding at 45 DAT	37.12	92.98	76.20	69.47	16.89
T_2- Oxadiargyl as pre-emergence @ 90 g a.i ha^{-1} + one hand weeding at 45 DAT	35.73	88.45	74.70	68.68	20.74
T_3- Oxyflourfen pre-emergence @ 0.15 kg a.i ha^{-1} + one hand weeding at 45 DAT	36.61	88.71	74.63	68.28	20.94
T_4- Pendimethalin C.S as pre-emergence @ 0.70 kg a.i ha^{-1} followed by quizalofop- ethyl @ 50 g a.i ha^{-1} at 15 to 20 DAT	52.97	64.86	54.66	56.56	29.82
T_5- Oxadiargyl pre-emergence @ 90 g a.i ha^{-1} followed by quizalofop-ethyl @ 50 g a.i ha^{-1} at 15 to 20 DAT	50.99	61.01	51.19	54.16	30.22
T_6- Oxyfluorfen pre-emergence @ 0.15 kg a.i ha^{-1} followed by quizalofop-ethyl @ 50 g a.i ha^{-1} at 15 to 20 DAT	60.82	68.87	56.16	53.5674	30.68
T_7- Pendimethalin C.S as pre-emergence @ 0.70 kg a.i ha^{-1} followed by propaquiza fop @ 62.5 g a.i ha^{-1} at 15 to 20 DAT	50.33	62.87	51.26	53.02	32.47
T_8- Oxadiargyl pre-emergence @ 90 g a.i ha^{-1} followed by propaquiza fop @ 62.5 g a.i ha^{-1} at 15 to 20 DAT	52.60	64.05	56.69	53.65	33.44
T_9- Oxyfluorfen pre emergence @ 0.15 kg a.i ha^{-1} followed by propaquiza fop @ 62.5 g a.i ha^{-1} at 15 to 20 DAT	52.82	63.04	53.37	49.91	32.87
T_{10}- Glyphosate @ 1.5 kg a.i ha^{-1} directed spray 25 and 50 DAT	87.23	81.14	76.27	74.68	72.06
T_{11}- Intercultivation at 25 and 50 DAT	77.03	78.73	76.84	76.35	15.80
T_{12}- Hand weeding three times at 20,40 and 60 DAT	85.54	83.42	81.06	79.89	0
T_{13}- Control	-	-	-	-	70.25

DAT-days after transplanting

Table 2: Yield attributes as influenced by different weed management practices in brinjal.

Treatments	No. of fruits per plant	Average fruit weight (g)	Marketable Fruit yield(t ha^{-1})
T_1- Pendimethalin C.S as pre- emergence @ 0.70 kg a.i ha^{-1} + one hand weeding at 45 DAT	27.07	42.33	27.95
T_2- Oxadiargyl as pre-emergence @ 90 g a.i ha^{-1} + one hand weeding at 45 DAT	27.05	41.66	27.58
T_3- Oxyflourfen pre-emergence @ 0.15 kg a.i ha^{-1} + one hand weeding at 45 DAT	26.70	41.33	27.51
T_4- Pendimethalin C.S as pre-emergence @ 0.70 kg a.i ha^{-1} followed by quizalofop- ethyl @ 50 g a.i ha^{-1} at 15 to 20 DAT	22.20	38.60	24.42
T_5- Oxadiargyl pre-emergence @ 90 g a.i ha^{-1} followed by quizalofop-ethyl @ 50 g a.i ha^{-1} at 15 to 20 DAT	23.54	36.54	24.28
T_6- Oxyfluorfen pre-emergence @ 0.15 kg a.i ha^{-1} followed by quizalofop-ethyl @ 50 g a.i ha^{-1} at 15 to 20 DAT	22.34	35.78	24.12
T_7- Pendimethalin C.S as pre-emergence @ 0.70 kg a.i ha^{-1} followed by propaquiza fop @ 62.5 g a.i ha^{-1} at 15 to 20 DAT	23.75	35.46	23.50
T_8- Oxadiargyl pre-emergence @ 90 g a.i ha^{-1} followed by propaquiza fop @ 62.5 g a.i ha^{-1} at 15 to 20 DAT	20.30	35.70	23.16
T_9- Oxyfluorfen pre emergence @ 0.15 kg a.i ha^{-1} followed by propaquiza fop @ 62.5 g a.i ha^{-1} at 15 to 20 DAT	22.28	34.92	23.36
T_{10}- Glyphosate @ 1.5 kg a.i ha^{-1} directed spray 25 and 50 DAT	23.59	26.33	9.72

T_{11}- Intercultivation at 25 and 50 DAT	27.12	42.66	28.92
T_{12}- Hand weeding three times at 20,40 and 60 DAT	28.46	45.33	31.10
T_{13}- Control	21.69	28.33	10.35
S.Em ±	0.53	0.54	0.17
CD (5%)	1.55	1.60	0.52

Table 3: Economics as influenced by different weed management practices in brinjal.

Treatments	Gross returns (Rs.ha^{-1})	Cost of cultivation (Rs.ha^{-1})	Net returns (Rs.ha^{-1})	B:C ratio
T_1 - Pendimethalin C.S as pre- emergence @ 0.70 kg a.i ha^{-1} + one hand weeding at 45 DAT	338520	50180	288340	5.75
T_2- Oxadiargyl as pre-emergence @ 90 g a.i ha^{-1} + one hand weeding at 45 DAT	330960	50285	280675	5.58
T_3- Oxyflourfen pre-emergence @ 0.15 kg a.i ha^{-1} + one hand weeding at 45 DAT	330120	50316	279804	5.56
T_4- Pendimethalin C.S as pre-emergence @ 0.70 kg a.i ha^{-1} followed by quizalofop- ethyl @ 50 g a.i ha^{-1} at 15 to 20 DAT	293040	48520	244520	5.04
T_5- Oxadiargyl pre-emergence @ 90 g a.i ha^{-1} followed by quizalofop-ethyl @ 50 g a.i ha^{-1} at 15 to 20 DAT	291360	48625	242735	4.99
T_6- Oxyfluorfen pre-emergence @ 0.15 kg a.i ha^{-1} followed by quizalofop-ethyl @ 50 g a.i ha^{-1} at 15 to 20 DAT	289440	48656	240784	4.95
T_7- Pendimethalin C.S as pre-emergence @ 0.70 kg a.i ha^{-1} followed by propaquiza fop @ 62.5 g a.i ha^{-1} at 15 to 20 DAT	282000	47748	234252	4.91
T_8- Oxadiargyl pre-emergence @ 90 g a.i ha^{-1} followed by propaquiza fop @ 62.5 g a.i ha^{-1} at 15 to 20 DAT	280320	47853	232467	4.86
T_9- Oxyfluorfen pre emergence @ 0.15 kg a.i ha^{-1} followed by propaquiza fop @ 62.5 g a.i ha^{-1} at 15 to 20 DAT	277920	47884	230036	4.80
T_{10}- Glyphosate @ 1.5 kg a.i ha^{-1} directed spray 25 and 50 DAT	116640	47703	68937	1.44
T_{11}- Intercultivation at 25 and 50 DAT	347040	49820	297220	5.96
T_{12}- Hand weeding three times at 20,40 and 60 DAT	373200	66800	306400	4.59
T_{13}- Control	124200	45800	78400	1.71

Conclusion

On the basis of results obtained in this study, it was concluded that, the treatment hand weeding three times at 20, 40 and 60 DAT recorded the highest yield attributes, whereas in case of BC ratio, inter cultivation at 25 and 50 DAT followed by pendimethalin C.S as pre-emergence @ 0.70 kg a.i ha^{-1} + one hand weeding at 45 DAT treatment recorded the highest values.

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