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Effects of various weed management practices on growth, yield and economics of *Rabi* onion (*Allium cepa* L.) cv. Bhima Shakti

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Abstract
The onion (*Allium cepa* L.) is a short-lived, shallow-rooted vegetable crop found throughout India, and it is more susceptible to weed infestation. Weed is creating havoc all over the world. It is a silent killer of crops. Productivity goes down, making farmers baffled. Weeds pose a serious problem in the successful cultivation of onions. Hand weeding is time-consuming, costly, and labor-intensive. This situation makes it necessary to use herbicides for effective and timely control of weeds in this crop. It is thus highly imperative to schedule a suitable method of weed control by the application of different herbicides to enhance profit for the onion growers in the country. With this background, an experiment was conducted at the research farm, Maharajpur, college of agriculture, Jawaharlal Nehru Agriculture University, Jabalpur (MP) in 2019–20. The experiment was carried out in a split plot design (SPT) with different weed management practices like Pendimethalin 1.0 kg/ha (PE), Oxyfluorfen 250 g/ha (POE), Propaquizafop 100 g/ha (POE), two-hand weeding at 20 and 40 DAT, and control (weedy check). The results of the experiment showed that the weed control practices had significantly affected all the studied parameters. The lowest weed density, weed dry weight, and weed index were found in hand weeding at 20 and 40 DAT (9.65 m-2, 5.57 g-2,and 7.01%, respectively) and high weed control efficiency (70.40%), closely followed by post-emergence application of Oxyfluorfen as compared to other weed control practices like Pendimethalin and Propaquizafop. The maximum average weight of bulb, bulb yield /plot, marketable bulb yield recorded in the hand weeding at 20 and 40 DAT (42.45 g, 15.15 kg and 24.58 t/ha, respectively) with at par Oxyfluorfen 250 g/ha (42.25 g, 14.44 kg, and 23.76 t/ha, respectively) but manual weeding are more laborious, costly and time taking practices due to Oxyfluorfen 250 g/ha noted highest net monetary return and B:C ratio (3,19,729.85 Rs/ha and 3.05).

Keywords: PE-Pre-emergence, POE-Post-emergence, weed control efficiency, weed index, oxyfluorfen, onion

Introduction

The onion (*Allium cepa* L.) (2n = 16) belongs to the Alliaceae family and is one of the most important bulbous vegetable crops. Considered to have originated in central Asia. India is the second largest producer of onions in the world, next to China, but the productivity of onions in India is very low, *i.e.*, 14.21 tons/ha, as compared to China and other countries like Egypt, the Netherlands, Iran, etc. In India, it is being grown on an area of 1.43 m ha with a production of an average of 26.15 MT, and the productivity is 16.18 tonnes per hectare, which is quite low (DAC & FW 2019-20). The major onion producing states are Maharashtra, Madhya Pradesh, Karnataka, Rajasthan, Gujarat, Bihar, Andhra Pradesh, Haryana, West Bengal, Uttar Pradesh, and Chhattisgarh in the country. These states account for almost 90% of the total onion production in the country. (SDH & A2020). One of the main reasons for the low productivity of the onion crop is the unawareness of the farmers about improved agronomic practises like micro irrigation, INM, IWM, use of micro nutrients, etc. The onion crop is more prone to weed menace and is usually infested by a wide spectrum of broad-leaf and grass weeds. Weeds compete with the crop for water, soil nutrients, light and space and thus reduce the bulb yield of onion crops considerably. Weed infestation is one of the limiting factors in growth and bulb production in onions. Hand weeding is time-consuming, costly, and labor-intensive. This situation makes it necessary to use herbicides to effectively and timely control weeds in this crop. Proper and timely weed control measures are essential for good bulb development in onions. It is thus highly imperative to schedule a suitable method of weed control by the application of different herbicides like Pendimethalin, Oxyfluorfen, and Propaquizafop in comparison with weedy check.

Weeds are one of the main plant protection problems in onion fields. They compete with onions for light, nutrients, water, and space and are also host plants for several harmful insects and pathogens (Ghoshel, 2004, Qasem, 2006, Smith *et al*., 2008) [9, 22, 25]. As in many crops, weeds cause yield reduction in onions owing to slow emergence, low initial growth rate, long vegetative period, and low competitive ability of the crop (Boyham *et al*., 2016) [15]. Onions are poor competitors against weeds due to their slow, vertical growth that fails to shade out weeds. Uncontrolled weed growth reduced onion bulb yield by 49 to 86 percent when compared to the best herbicidal treatment (James and Harlen, 2010) [11] of effective and economically viable weed management options for onion production has been reported as a critical constraint affecting farmers' motivation to grow the crop. The conventional methods of weed control, i.e. hand weeding and hoeing, are very laborious, time-consuming, and expensive. Weedicides applied at the preemergence stage, significantly controlled the weed population (Nargis *et al*., 2006) [18]. Post–emergence herbicides, according to Panse *et al*. (2014) [19], kill weeds and keep hardy weeds under control by arresting their growth through various types of deformities in foliage and growing points. For controlling weeds, integrated management through cultural, mechanical, and herbicidal methods could be more efficient than single methods because onion is a narrow-leaved crop and the herbicides that do not herm onion also may not herm the narrow-leaved weed.

Materials and Methods

The investigation was carried out during the *Rabi* season (Dec-May) 2019-20 at Maharajpur Vegetable Research Farm, Department of Horticulture, JNKVV, Jabalpur (MP), India. The climate of the Jabalpur region is typically sub-humid, characterised by hot, dry summers and cool, dry winters. The mean annual rainfall of Jabalpur is 962 mm and ranges from 1000 to 1500 mm. The soil of the experimental field is sandy clay loam in texture, medium in organic carbon (0.58%), available nitrogen (218.00 kg N ha-1) and phosphorus (12.22 kg P2O5 ha-1) but high in available potassium (289 kg K2O ha-1). The soil was nearly neutral in reaction (6.6pH) and the concentration of soluble salts (0.15 ds m^{-1}) was below the harmful limit. The treatment consisted of two weed management practises (mechanical and chemical). Treatment details were as follows: Hand weeding at 20 and 40 DAT, control (weedy check), and pendimethalin 1.0 kg/ha (PE), oxyfluorfen 250 g/ha (POE), propaquizafop 100 g/ha (POE).

Application of herbicides

The quantity of herbicides for the respective plots was determined according to the active ingredient present in the commercial products. The spraying of herbicides was done by mixing the exact quantity of herbicides into a measured quantity of water at the rate of 500 litres ha-1. The measured quantity of herbicide and water for each plot was mixed thoroughly before spraying. Herbicides were applied to the respective plots by a knapsack sprayer using a flat fan nozzle.
The required amount of herbicides for the experiment was calculated by using the following formula.

$$\text{Required Chemical } = \frac{\frac{ai}{ha}}{EC\%} X\ 100$$

Hand weeding was carried out as per treatment. Weed-free zones were hand-weeded on a regular basis as the weeds appeared. In farmers' practice, two hand weeding was carried out at 20 and 40 DAT.

Density (m-2) and dry weight (g) by species at 60 DAT (0.25m2): The number of weeds present in a $0.25m^2$ area of each plot selected randomly each time was counted at 60 DAT. They were further counted with numbers, and dry weights of weeds were recorded at 60 DAT. The weeds were uprooted from the $0.25m^2$ area and sun dried for about 9–10 days, and the dry weight of the weeds in each treatment was recorded.

Weed control efficiency (%): Weed control efficiency (WCE) denotes the magnitude of weed reduction due to the weed control treatment. The weed control efficiency was calculated by using the formula and could be expressed as below.

$$\text{WCE\%} = \frac{\text{WPC} - \text{WPT}}{\text{WPT}} \text{X } 100$$

Where, WCE = Weed control efficiency, DWC = Dry weight of weeds in control plots, DWT = Dry weight of weeds in treated plots.

Weed index (%): Weed competition index indicates the decrease or increase in yield of weeded and treated plots affected by the crop weed competition and it is calculated by the formula

$$\text{Weed index } = \frac{\text{X} - \text{Y}}{\text{X}} \text{X } 100$$

Where, X = Weeded check yield, Y = Treatment yield

Yield parameter

Average bulb weight (g)/plot (kg)/ha (t.) To calculate the weight of bulbs in each plot, five plants were randomly selected and weighed on an electronic balance after cutting the leaves from 2–2.5 cm above the neck. Finally, the average weight of bulbs in each plot was calculated in grams. Bulbs were weighed on an electronic balance and bulb yield per net plot was recorded in kilograms, which was converted into tonnes per hectare as given below:

$$\text{Total bulb yield (t/ha) } = \frac{\text{bulb yield (kg/plot)x } 10{,}000}{net\ area\ of\ plot\ (m2)x10x\ 100}$$

Marketable bulb yield (t/ha)

The weight of damaged, doubles, and small bulbs was deducted from the total yield per net plot and the balance was converted into marketable yield/ha as given below:

$$\text{Marketable bulb yield (t/ha) } = \frac{(\text{w1}-\text{w2})\text{x } 10{,}000}{net\ area\ of\ plot\ (m2)x\ 10x10100}$$

Where, W1 is the total bulb weight per net plot, W2-Bulb weight per net plot that is unmarketable

Economic evaluation: The cost of cultivation (Rs/ ha)

The cost of cultivation refers to the total expenses incurred in cultivating one hectare of crop (Rs ha^{-1}). Total cultivation cost = total variable cost + total fixed cost.

Gross monetary returns per hectare (Rs/ha): The gross rate of return is the total rate of return on an investment before the deduction of any fees, commissions, or expenses.

Net financial returns (Rs/ha): The net monetary returns (NMR) per hectare were calculated by considering the gross monetary returns and the cost of cultivation. Net monetary returns (Rs.) = Gross monetary return – Total cultivation cost
Benefit–cost ratio:- The benefit-cost ratio was worked out by considering the per hectare values of gross monetary returns and the cost of cultivation. It was calculated by using the following formula:

$$\text{benifit cost ratio (Rs)} = \frac{\text{gross monetary return(Rs)}}{\text{cost of cultivation (Rs)}}$$

Results and Discussion

There was a significant effect on weed, yield, and economic contributing characteristics of onion bulbs as influenced by different herbicide application practices. The common weed flora found in onion crops are *Cyperus rotundus, Cynodon dactylon, Medicago denticulata, Cichorium intybus, Melilotus indica, and Chenopodium album.* The results of the study (Table 1) showed that weed management practises had significant variation in weed density (Wd) and weed dry weight (WDW) for both monocots and dicots weeds compared with the control (weedy check) and weed index (WI) and increased the weed control efficiency (WCE).

At 60 DAT, weed density (m-2) (WD), weed dry weight (WDW), weed index (WI), and weed control efficiency (WCE) were measured

The weed control practices had a markedly significant influence on the density and dry weight of the weeds of onion over control (weedy check). The weed density, dry weight, and weed index were recorded as maximum and minimum weed control efficiency under control (weedy check) plots where weed control was not done, but was recorded appreciably in plots receiving either mechanical or chemical weed control. Two hand weeding and post-emergences herbicide application of Oxyfluorfen 250 g/ha recorded a significantly lower minimum density of weeds as compared to Propaquizafop 100 g/ha, Pendimethalin 1.0 kg/ha, and control (weedy check) during mean values at 60 DAT. The density and dry weight of weeds were found maximum in control (weedy check) (18.26 m^{-2}, 9.71 g^{-2},55.18%, and 6.41%, respectively) over other weed control practices followed by Pendimethalin (15.48 m^{-2}, 8.23 g^{-2}, 27.80% and 32.05%), Propaquizafop (11.89 m^{-2}, 6.70 g^{-2}, 16.78% and 54.65%, respectively) and Oxyfluorfen (10.78 m^{-2}, 6.10 g^{-2}, 10.12% and 63.45%, respectively), while hand weeding at 20 and 40 DAT was recorded minimum weeds density (9.65 m^{-2} and 5.57 g^{-2}, 7.01% and 70.40%, respectively) during mean values at 60 DAT. Accordingly, the highest density and dry weight of weeds were observed with an unweeded control during both years of study. Hand weeding at 20 and 40 DAT might have completely removed all types of weeds, including sedges, during the critical period of crop-weed competition (20–45 DAT). Pre-emergence application of either oxyflourfen or pendimethalin might have effectively hindered the germination of weed seeds and reduced the weed dynamics of grasses and broad leaved weeds, but they were found to be least effective against sedges. But supplementing hand weeding at 40 DAT might have reduced the weed density and dry weight effectively, similar results found by Chandrika *et al*. (2009) [6] as well as It was due to the hand weeding imposed at 40 DAT in the weed management practises that the weeds were controlled effectively, as evident from the reduced dry matter production of weeds. The findings of Prakash *et al*. (2000) [21], Khan *et al*. (2021) [16], and Gaharwar *et al*., 2017 [8]; Chattopadhyay *et al*., 2016 [7]; and Patel *et al*., 2012) [20] are supported by the data. The lowest dry weight was achieved by applying twice the herbicides PE and POE, and the current finding of WCE corroborates the findings of several researchers. Significantly higher WCE was observed under weed free conditions, also published by Vishnu *et al*. (2015) [28], Sahoo *et al*. (2017) [24], and Ramalingam *et al*. (2013) [23].

Table 1: Shows the effect of various weed management practices on weed density (WD), weed dry weight (WDW), weed index (WI), and weed control efficiency (WEC) on Rabi onion at 60 DAT

Weed control practices	WD (m^{-2})	WDW (g^{-2})	Weed index	WCE%
Pendimethalin stomp 38.7% EC PE	15.48	8.23	27.80	32.05
Oxyfluorfen Goal 23.5% EC POE	10.78	6.10	10.12	63.47
Propaquizafop Agil 10% EC POE	11.89	6.70	16.78	54.65
Hand weeding (20 and 40 DAT)	9.65	5.57	7.01	70.40
Control (weedy check)	18.26	9.71	55.18	6.41
S.Em±	0.36	0.17		
CD at 5%	1.05	0.49		

WD- Weed density, WDW- Weed dry weight, WEC- Weed control efficiency

Onion yield parameters

Two-hand weeding and post emergence herbicide application of Oxyfluorfen 250 g/ha recorded significantly higher average weight of bulb and bulb yield per plot as compared to Pendimethalin at 1.0 kg/ha, Propaquizafop 100 g/ha over control (weedy check) during mean values at harvesting stages of the crop (Table 2).Two hand weeding at 20 and 40 DAT was noted maximum average weight of bulb and bulb yield (43.91 g and 15.15 kg, respectively) with at par Oxyfluorfen 250 g/ha (42.90 g and 14.44 kg, respectively) followed by Pendimethalin at 1.0 kg/ha (39.26 g and 13.43 kg), Propaquizafop 100 g/ha (34.92 g and 11.62 kg), while, weedy check was noted minimum average weight of bulb and bulb yield (23.38 g and 7.76 kg) during mean values at harvesting of crop. It might be due to less weed crop competition throughout the crop growth period by manual weeding, which in turn maintains the soil fertility status by way of removing fewer plant nutrients through weeds and ultimately has a favourable effect on growth parameters and yield attributes. These findings are in close conformity with those reported by Ved Prakash *et al*. (2000) [21], Bharathi *et al*. (2011) [4], Kalhapure and Shete (2012) [12], and Kalhapure *et* *al*. (2013) [13]. The findings are in close proximity to those of Thakare *et al*. (2018) [27] and Gupta *et al*. (2019) [10].

Total bulb yield (t/ha) and marketable bulb yield (t/ha)

Hand weeding and post emergence herbicide application of Oxyfluorfen recorded significantly higher total bulb yield as compared to Pendimethalin and Propaquizafop over weedy check during mean values both years at harvest. Two-hand weeding at 20 and 40 DAT yielded the highest total bulb yield (25.89 t/ha), followed by Oxyfluorfen (24.68 t/ha), Pendimethalin (22.94 t/ha), and Propaquizafop (19.85 t/ha), while weedy check yielded the lowest total bulb yield (24.58 t/ha) during mean values at harvest, a nearly identical result recorded on the lowest yield was recorded in weedy check plots owing to low chlorophyll content and photosynthetic rate due to un-checked weed growth there by reducing the availability of moisture, light, and nutrients to the crop, thus resulting in a loss of yield. The maximum yield was recorded in the weed free plot followed by other manual/herbicidal treatments. The favourable environmental conditions created by the clean crop culture resulted in more absorption of solar radiation and plant nutrients, which ultimately resulted in more photosynthetic rates and dry matter accumulation (Angmo *et al*., 2018) [1]. Similar results are also published by Khan *et al*. (2013) [15].

Table 2: Shows the effect of various weed management practices on average bulb weight (g), bulb yield per plot (kg), total and marketable bulb yield (t/ha) at *Rabi* onion harvest

Weed control practices	AWB (g)	BYP (kg)	TBY (t/ha)	MBY (t/ha)
Pendimethalin stomp 38.7% EC PE	38.13	13.43	22.94	22.00
Oxyfluorfen Goal 23.5% EC POE	41.25	14.44	24.68	23.76
Propaquizafop Agil 10% EC POE	33.26	11.62	19.85	19.08
Hand weeding (20 and 40 DAT)	42.45	15.15	25.89	24.58
Control (weedy check)	21.16	7.76	13.26	11.85
S.Em±	0.62	0.33	0.557	0.381
CD at 5%	1.79	0.94	1.604	1.096

Average weight of bulb (AWB), bulb yield of per plot (BYP), Total bulb yield (TBY), Marketable bulb yield (MBY)

The impact of weed management practices on onion economics

The economics of onion crops imposing different weed management practices were worked out in respect of the cost of cultivation, gross monetary return, net monetary return, and finally the benefit-cost ratio, which are shown in (Table 3). The cost of cultivation was calculated treatment by treatment based on the market price of various common and variable agro-inputs used in the Jabalpur region of Madhya Pradesh. The highest cost of cultivation was obtained on two-hand weeding at 20 and 40 DAT (1,82,595.00 Rs/ha), followed by Pendimethalin 1.0 kg/ha (1,56,418.50 Rs/ha), and the lowest cost of cultivation was obtained on control (1,53,195.00 Rs/ha). The highest gross return maximum on hand weeding was at 20 and 40 DAT, but the highest net monetary return and B:C ratio were attained on Oxyfluorfen Goal 23.5% EC POE 250 g/ha (3,19,729.85 Rs/ha and 3.05, respectively) and control (weedy check) recorded the lowest net monetary return and B:C ratio (83,829.73 Rs/ha and 1.55, respectively). This is because hand weeding is much more laborious than spraying with herbicides, which is also expensive and time-consuming. Similar results are also reported by Panse *et al*. (2014) [19] and Kalhapure *et al*. (2014) [14].

Table 3: Effects of different weed management practices on the economics of *Rabi* onion production

Weed control practices	Cost of cultivation	Gross monetary return	Net monetary return	B: C ratio
Pendimethalin stomp 38.7% EC PE	156418.50	440036.2	283617.66	2.81
Oxyfluorfen Goal 23.5% EC POE	155557.50	475287.3	319729.85	3.05
Propaquizafop Agil 10% EC POE	155305.50	381762.1	226456.63	2.46
Hand weeding (20 and 40 DAT)	182595.00	491717.6	309122.60	2.69
Control (weedy check)	153195.00	237024.7	83829.73	1.55

4. Conclusion

From the present investigation, it could be concluded that two-hand weeding at 20 and 40 DAT recorded higher marketable bulb yield, weed control efficiency, and the lowest weed density, weed dry weight, and weed index because the removal of weed by hand is laborious, costly, and time-consuming. This condition makes it necessary to use herbicides for effective and timely control of weeds in the crop. Closely followed by post-emergences Oxyfluorfen 250 g/ha application were recorded maximum marketable bulb yield, net monetary return, and B: C ratio (3.05) were recorded in *Rabi* season grown onion in the Jabalpur region.

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