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RESEARCH ARTICLE

Integrated weed management in ginger for higher productivity in coastal zone of Odisha

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ABSTRACT

Ginger (*Zingiber officinale)* is highly susceptible to weed infestation because of its slow initial growth. The weed problem severely influences crop productivity and economic returns. Mostly the weed control strategies rely on the manual method which is costly and time-consuming. Therefore, the current investigation was carried out at the central research farm of Odisha University of Agriculture and Technology, Bhubaneswar, Odisha, India in 2014-2016 to find out the effective and feasible methods for weed control in ginger. Nine treatments which included the use of pendimethalin, oxyfluorfen, pendimethalin followed by (*fb*) hand weeding, oxyfluorfen *fb* hand weeding, glyphosate, glyphosate + pendimethalin, glyphosate + oxyfluorfen, 4 hand weeding and unweeded control. Among the treatments, tank mix application of glyphosate + pendimethalin was most effective in controlling weeds with high weed control efficiency (53.8%), minimum weed index (1.09%) and weed persistence index (0.49) as compared to other treatments. Pre-emergence application of glyphosate + pendimethalin also resulted in the highest rhizome yield 27.2 t/ha and B: C of 3.78. Hence, tank mix of Glyphosate 0.80 kg/ha + pendimethalin 1.5 kg/ha applied after mulching and just before emergence of sprouts of ginger is a remunerative method in controlling weeds effectively and giving highest yield in Coastal zone of Odisha.

Key words: B: C ratio, weeds control efficiency, weed index, weed persistence index, *Zingiber officinale*

INTRODUCTION

Ginger (*Zingiber officinale* Roscoe) of the family *Zingiberaceae*, is an herbaceous perennial, usually grown as an important commercial annual spice crop. Srinivasan *et al*. (2018) reported that ginger is extensively cultivated for its flavor, pungency, aroma and healing characteristics associated with its essential oil and oleoresin contents. India has the largest share in the total area under ginger cultivation (34.6%) and annual production (29%) in the world and exports 10–15% of its produce (Kallappa *et al*. 2015). As per the reports of the National Horticulture Board, 2021-22, among the ginger-producing states in India, Madhya Pradesh contributes the highest share of 31.18% while Odisha contributes 5.77%. The low production of ginger in Odisha is due to weed infestation. As the crop is of long duration and slows in sprouting, it is highly susceptible to weed competition, especially at the initial stages of crop growth resulting in higher yield loss. All India Coordinated Research Project on Weed management, Kerala center, has reported that uncontrolled weed growth leads to a significant reduction in ginger yield, ranging from 30% to 45% (KAU, 2006). Osunleti *et al*. (2021) reported that there is a reduction of 91.9% and 92.1% rhizome yield reduction in 2016 and 2017, respectively due to weed infestation. Weeds compete with ginger for moisture, nutrients, and space. Weed competition has also been identified as a constraint to root and rhizome production. In practice, two to three-hand weeding is done depending on the weed intensity and growth. The manual method of weed control is not effective and economical considering the intensity of weed persistence, labor charges and availability. The use of herbicides is an important practice for most crops as it is easier, has superior weed control efficacy (Roy *et al*. 2023), increases yields (Baruah and Deka 2020), time and labor-saving and is economical compared to other weed control measures (Rekha *et al*. 2003). Hence, this study was formulated to identify a remunerative approach in controlling weeds in ginger in the Coastal Zone of Odisha.

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MATERIALS AND METHODS

A field experiment was conducted for two years (2014–15 and 2015–16) at the central research farm of Orissa University of Agriculture and Technology (OUAT), Bhubaneswar (20°152 N, 85°482 E, 30.6 m ASL). The region is designated by subtropical climate having an average annual rainfall of 1484 mm. The experimental soil status was sandy clay loam having uniform texture up to a depth of 100 cm. The soil pH was 6.4 and EC was 0.18dS/m with organic carbon of 4.8 g/kg, available N, P and K were 143.5 kg/ha, 38.5 kg/ha and 117 kg/ha, respectively. The experiment was laid out in randomized block design with three replications. The experimental field was cultivated and leveled. Farm yard manure was applied at 10 t/ha. The ginger variety '*Suruchi*' was sown in raised beds of 5m × 1m on 8th July 2014 and harvested on 16th March 2015 in the first year and second year sowing was done on 28th June 2015 which was harvested on 24th February 2016. Paddy straw mulch was applied 5 t/ha in plots 7 days after sowing (DAS).

In total 9 herbicidal treatments: Pendimethalin 1.5 kg/ha applied after sowing but before mulching; oxyfluorfen 0.20 kg/ha applied after sowing but before mulching; pendimethalin 1.5 kg/ha applied after sowing but before mulching followed by (*fb*)HW at 30-35 days after planting (DAP); oxyfluorfen 0.20 kg/ha applied after sowing but before mulching *fb* HW at 30-35 DAP; glyphosate 0.80 kg/ha applied after mulching and just before emergence of sprouts of ginger; tank mix of Glyphosate 0.80 kg/ha+ pendimethalin 1.5 kg/ha applied after mulching and just before emergence of sprouts of ginger; tank mix of glyphosate 0.80 kg/ha+ oxyfluorfen 0.2 kg/ha applied after mulching and just before emergence of sprouts of ginger; four hand weeding at 20, 40, 60 and 90 DAP; weedy check. Pre-emergence application of herbicides like oxyfluorfen and pendimethalin was done in respective treatments at 2 days after sowing (DAS). The post-emergence herbicide like glyphosate was applied sole at 0.8 kg/ha and along with other pre-emergence herbicides at 10 DAS (after mulching and just before the emergence of sprouts of ginger). The density of weeds consisting of grasses, sedges and broad-leaved weeds was estimated by taking a quadrate of 0.5 × 0.5 m at three randomly selected places in each plot at 30, 60 and 90 DAS. After measuring, the roots were separated from the shoots and were oven-dried at 70±1°C for 72 hours and weighed to record the weed-dry biomass. It was expressed in per m^2.

Further, the weed indices were calculated as follows:

Weed control efficiency (WCE) defines the effect of treatments in controlling the weeds based on weed dry weight. WCE was determined by the formula given by Mani *et al.* (1973) as follows:

$$WCE(\%) = \frac{X - Y}{X} x\ 100$$

Where, X = Weed dry matter in weedy check and Y = Weed dry mater in treatment plot

Weed index (WI) defines the percent reduction in yield due to the presence of weeds in the treated plot in comparison to the yield obtained in the weed-free plot. It is computed by using the following formulas suggested by Gill and Kumar (1969):

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

Where, X= yield in weed free plot and Y = yield in treated plot

Weed persistence index (WPI) specifies the resistance in weeds against the treated herbicide and confirms its effectiveness. It is calculated by the formula outlined by Mishra and Mishra (1997)

$$WPI = \frac{Drymatterofweedintreatedplot}{Drymatterofweedsincontrolplot} x \frac{Weedcountincontrolplot}{Weedcountintreatedplot}$$

The rhizome yield was estimated by taking the weight of the produce from an area of 1m × 1m and then converted into t/ha. Economic analysis was carried out by calculating the cost of cultivation by taking the cost of land preparation, rhizome and manure, chemicals, labour, and mulch materials, etc. into account. The wholesale market price of the produce was used to calculate the gross and net returns and the benefit: cost (B:C) was calculated taking gross return over cost of cultivation.

All experimental data were analyzed by analysis of variance (ANOVA) using STAR 2.0.1.For normalization of weed data the square root transformation ("X) was performed and then analyzed. Treatment means were compared by critical difference (CD) at 5% probability (p=0.05).

RESULTS AND DISCUSSION

The common weed species at the site of study included grasses like *Cynodon dactylon, Digitaria ciliaris, Dactyloctenium aegyptium*: sedges included *Cyperus rotundus* and *Cyperus esculentus* and broad-leaved weeds included *Phylllanthus niruri,Ageratum conyzoides, Oxalis latifolia, Solanum nigrum, Physalis minima, Commelina benghalensis* and *Euphorbia hirta.*

Among all the treatments, weed density was found to be the lowest in hand-weeded plots and the plots applied with glyphosate + pendimethalin (**Table 1**). The weed density increased upto 90 DAS. Since the emergence and early growth of ginger is inherently slow and there is considerable time elapse between sowing and development of foliage cover, the crop competes very poorly with weeds (Thankamani *et al*. 2016). However, weed biomass (g/m^2) was found to be the least with the application of glyphosate at all the stages (30, 60 and 90DAS) (**Table 2**).

Weed indices are used to draw interpretations regarding better treatment in weed control. The highest weed control efficiency (WCE) was observed in the pre-emergence herbicide use of glyphosate + pendimethalin (53.8%) at 90 DAS followed by pendimethalin *fb* hand weeding and oxyfluorfen *fb* hand weeding (39.1) (**Table 3**). The WCE was 83% higher than the hand-weeded plot. Weed control efficiency which indicates the comparative magnitude of reduction in weed dry matter was highly influenced by different weed control treatments. Similar results were obtained by Sah *et al*. (2017).

Weed index indicates the percent yield loss caused due to weeds as compared to a weed-free check. The results reveal that the lowest value of WI was obtained with the combined under hand weeding where the field was kept weed free followed by the herbicidal treatment of glyphosate + pendimethalin (1.09%). Also, a higher yield loss was observed in weedy check plots followed by using pendimethalin alone. Since ginger is a long-duration crop, its initial growth is slow and it faces a lot of competition with weeds at the initial stage. Hence application of pre-emergence herbicides in combination controlled the weeds effectively.

Weed persistence index indicating relative dry matter accumulation of weeds per count (**Table 3**) indicated that the combined application of glyphosate

Table 1. Effect of weed management on weed density of ginger (2014-15 and 2015-16)

Treatment	Weed density (no./m^2)					
	2014-15			2015-16		
	30 DAS	60 DAS	90 DAS	30 DAS	60 DAS	90 DAS
Pendimethalin	4.52(20.5)	5.23(27.1)	6.74(45.5)	4.39(19.3)	5.08(25.9)	6.59(43.5)
Oxyfluorfen	4.3(18.5)	4.67(21.9)	6.20(39.5)	4.11(16.9)	4.84(23.5)	6.43(41.1)
Pendimethalin *fb* hand weeding	3.34(11.18)	3.72(13.9)	5.36(28.8)	3.19(10.22)	3.93(15.5)	5.53(30.6)
Oxyfluorfen *fb* hand weeding	3.70(13.7)	4.97(24.8)	6.23(38.9)	3.86(14.9)	5.07(25.8)	5.87(34.5)
Glyphosate	3.04(9.3)	4.72(22.9)	6.46(41.8)	2.66(7.1)	4.96(24.7)	6.54(42.8)
Glyphosate+ pendimethalin	2.38(5.7)	3.3(11.0)	6.28(39.5)	2.21(4.9)	3.09(9.6)	6.09(37.1)
Glyphosate + oxyfluorfen	2.94(8.7)	4.88(23.9)	6.89(43.5)	2.84(8.1)	5.10(26.1)	6.44(41.5)
Hand weeding (4)	4.51(20.4)	5.27(27.8)	6.69(44.8)	4.31(18.6)	4.9(24.5)	6.54(42.8)
Weedy check	4.85(23.6)	4.67(21.9)	5.50(30.3)	5.07(25.8)	4.52(20.5)	5.78(33.5)
LSD (p=0.05)	0.34	0.51	0.33	0.29	0.48	0.32

Data are the square root ($\sqrt{x+0.5}$) transformation of the original value in parentheses

Table 2. Effect of weed management on weed biomass (g/m^2) of ginger (2014-15 and 2015-16)

Treatment	Weed biomass (g/m^2)					
	2014-15			2015-16		
	30 DAS	60 DAS	90 DAS	30 DAS	60 DAS	90 DAS
Pendimethalin	2.97(8.85)	3.62(13.1)	5.66(32)	3.12(9.75)	3.5(11.89)	5.56(30.9)
Oxyfluorfen	2.89(8.40)	3.03(9.19)	5.14(26.5)	2.66(7.2)	2.93(8.01)	5.33(28.5)
Pendimethalin *fb* hand weeding	1.81(3.30)	2.55(6.53)	5.10(26.1)	1.58(2.5)	2.40(5.07)	5.02(25.3)
Oxyfluorfen *fb* hand weeding	2.60(7.1)	2.77(7.7)	5.27(27.8)	2.50(6.3)	2.68(6.7)	5.07(25.8)
Glyphosate	2.94(8.7)	3.10(10.2)	5.42(29.4)	2.58(6.7)	3.08(8.8)	5.05(25.6)
Glyphosate+ pendimethalin	1.89(3.6)	2.09(4.4)	4.49(20.2)	2.04(4.2)	1.94(3.2)	4.42(19.6)
Glyphosate + oxyfluorfen	2.81(7.9)	3.24(10.5)	5.24(27.5)	3.01(9.1)	3.13(9.1)	5.33(28.5)
Hand weeding (4)	3.08(9.5)	3.40(11.6)	5.53(30.6)	2.81(7.9)	3.24(9.4)	5.38(29.0)
Weedy check	4.80(23.1)	5.74(33)	6.57(43.2)	4.98(24.9)	5.64 (30.8)	6.41(41.2)
LSD (p=0.05)	0.34	0.55	0.33	0.24	0.31	0.24

Data are the square root ($\sqrt{x+0.5}$) transformation of the original value in parentheses

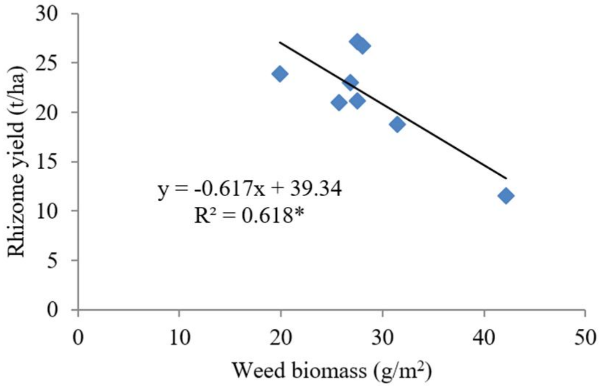

Figure 1. Relationship analysis of weed biomass at 90DAS and rhizome yield of ginger

+ pendimethalin gave the lowest WPI (0.49) followed by glyphosate + oxyfluorfen (0.71) (**Table 3**). Similar findings were also corroborated by Mishra *et al.* (2016).

The highest rhizome yield of 27.2 t/ha was obtained in the treatment of glyphosate + pendimethalin (**Table 4**). Since there is a negative relation between weed density and rhizome yield in ginger. Hence, due to less number of weeds in this treatment, the yield was higher. Similar results were obtained by Sah *et al.* (2017).

The economic parameters *i.e.* net returns and benefit: cost are influenced by herbicidal treatments in ginger. The maximum net returns were obtained under the hand-weeded plot and herbicidal treatment of glyphosate + pendimethalin with an amount of [1] . 1,85,000 (**Table 4**). The B: C was highest with the treatment of glyphosate + pendimethalin (3.78) which is at par with glyphosate, glyphosate + oxyfluorfen.

The regression analysis between weed biomass (g/m^2) and grain yield (t/ha) shows a significant negative correlation with an R^2 value of 0.618. The data showed that with per unit addition of weed biomass negatively affected the yield to the tune of 0.61%.

It can be concluded that the pre-emergence application of glyphosate + pendimethalin gave the highest weed control efficiency and maximum yield was also obtained. Hence, pre-emergence herbicide application of tank mix of glyphosate 0.8 kg/ha + pendimethalin 1.5 kg/ha applied after mulching and just before the emergence of sprouts substantially reduced the labor requirement and higher economic returns were obtained compared to the complete hand weeding situation.

Table 3. Effect of weed management on weed indices at 90 DAS in ginger (2014-15 and 2015-16)

Treatment	Weed control efficiency (%)		Weed Index (%)		WPI	
	2014-15	2015-16	2014-15	2015-16	2014-15	2015-16
Pendimethalin	26.5	24.3	30.39	32.89	0.82	0.70
Oxyfluorfen	35.6	34	21.83	23.99	0.69	0.77
Pendimethalin *fb* hand weeding	38.3	39.9	23.56	23.72	1.02	0.84
Oxyfluorfen *fb* hand weeding	38.2	34.8	17.02	15.7	0.84	0.72
Glyphosate	36.9	34.7	2.99	3.19	0.88	0.66
Glyphosate + pendimethalin	55.6	52	1.16	1.02	0.52	0.46
Glyphosate + oxyfluorfen	34.15	33.05	2.71	3.11	0.78	0.64
Hand weeding (4)	30.2	28.6	-	-	1.02	0.98
Weedy check	-	-	57.88	58.48	1.11	0.95

Table 4. Effect of weed management on rhizome yield, net returns and benefit: cost of ginger (pooled data of 2014-15 and 2015-16)

Treatment	Rhizome yield (t/ha)			Net returns ($\times 10^4$ Rs/ha)	Benefit: cost
	2014-15	2015-16	Pooled		
Pendimethalin	19.4	18.2	18.8	14.6	3.39
Oxyfluorfen	21.8	20.6	21.2	15.4	3.50
Pendimethalin *fb* hand weeding	22.4	19.6	21.0	15.4	3.39
Oxyfluorfen *fb* hand weeding	23.7	22.3	23.0	16.2	3.59
Glyphosate	24.6	23.2	23.9	16.5	3.72
Glyphosate+ pendimethalin	27.0	27.4	27.2	18.3	3.78
Glyphosate + oxyfluorfen	27.5	25.9	26.7	17.5	3.66
Hand weeding (4)	27.9	27.1	27.5	18.5	3.55
Weedy check	12.1	10.9	11.5	10.7	2.32
LSD (p=0.05)	0.94	0.87	0.84	0.75	0.42

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