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RESEARCH NOTE

Production potential and economics of integrated weed control measures in ginger

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ABSTRACT

A field experiment was carried out in 2014 and 2015 to evaluate the effect of integrated weed management on growth, yield, weed control efficiency and economics of ginger. The experiment was laid out in a randomized block design with nine integrated weed management treatments and three replications. The results revealed that hand weeding twice at 30 and 60 days after planting (DAP) recorded the lowest weed population 6.20 and 7.38/m^2, dry weight 11.80 and 10.23 g/m^2 at 75 DAP and the highest weed control efficiency (WCE) 85.0 and 86.6% in 2014 and 2015, respectively, which was followed by application of glyphosate 0.80 kg/ha + pendimethalin 1.5 kg/ha and glyphosate 0.80 kg/ha + oxyfluorfen 0.2 kg/ha before the emergence of sprouts of ginger in both years. However, glyphosate 0.80 kg/ha + pendimethalin 1.5 kg/ha (25 DAP) and glyphosate 0.80 kg/ha + oxyfluorfen 0.20 kg/ha (25 DAP) significantly improved the rhizome yield to the tune of 86.9, 81.5 and 91.8, 93.9% over the control during the years, respectively. The highest B: C (2.07) was obtained with glyphosate 0.80 kg/ha + oxyfluorfen 0.20 kg/ha (25 DAP) followed by unweeded control. Hence, it was concluded that for better ginger productivity and weed management two-hand weeding at 30 and 60 DAP; or application of glyphosate 0.80 kg/ha + oxyfluorfen 0.2 kg/ha is the most potential and viable practice.

Keywords: Economics, Ginger, Glyphosate + oxyfluorfen, Hand weeding, Yield, Weed control efficiency

Tropical and subtropical regions cultivate ginger (*Zingiber officinale* Roscoe) for its culinary and therapeutic uses. Ginger has been grown since ancient times and India is currently one of the world's top producers. This crop produces a good yield, and since it is a cash crop, its profitability is better than that of other crops growing at that time (Choudhary *et al*. 2015). Due to its guaranteed better yield, demand, and market availability, ginger farming has recently got a boost in the area (Kushwaha *et al*. 2013). Ginger is highly vulnerable to weed infestation, due to its slow emergence and long growing season. Weed causes yield losses and requires much monetary investment to save the crop (Rahaman *et al*. 2009).

In Bihar state of India, weeds are typically controlled manually, which is a time-consuming and an expensive process. Occasionally owing to a labour shortage and unexpected rains, hand weeding and mechanical operations are frequently either postponed or abandoned that frequently results in crop loss. Herbicides are also less effective due to the heavy rains, Moreover, continuous and intensive use of herbicide over a period of time leads to the development of resistant biotypes within the weed community (Singh *et al*. 2023). Organic mulching is also not standardized for this area, although it is an excellent way to control weeds in ginger (Chatterjee *et al*. 2011). Therefore, timely weed control is essential for optimizing the yield of ginger. Furthermore, the integration of different weed management practices holds great promise for effective, timely and economical weed management. Thus, the present study was carried out to quantify the efficacy of the integration of different weed management practices and herbicides used either alone or in combination with other herbicides at different times to manage weeds and improve ginger yield.

A field study was conducted during two successive years (2014 and 2015) at the Agricultural Research Farm of Tirhut College of Agriculture, Dholi, Dr. RPCAU, Pusa. The experiment was laid out in a randomized block design with 3 replications. The experiment was comprised of nine weed management treatments follows: pendimethalin 1.5 kg/ha (after planting but before mulching (20 days after planting, DAP)); oxyfluorfen 0.20 kg/ha (after

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planting but before mulching (20 DAP)); pendimethalin 1.5 kg/ha *fb* hand weeding (after planting but before mulching (20 DAP) *fb* 30-35 DAP); oxyfluorfen 0.20 kg/ha *fb* hand weeding (after planting but before mulching (20 DAP)) *fb* 30-35 DAP); glyphosate 0.80 kg/ha (just before emergence of sprouts of ginger (25 DAP); glyphosate 0.80 kg/ha + pendimethalin 1.5 kg/ha (just before emergence of sprouts of ginger (25 DAP)); glyphosate 0.80 kg/ha + oxyfluorfen 0.20 kg/ha (just before emergence of sprouts of ginger (25 DAP); hand weeding (twice at 30 and 60 DAP); unweeded control. The soil of the experimental plot was sandy loam in texture, alkaline in reaction (pH 8.52), low in organic carbon (0.44 %), available N (272 kg/ha), P (18.05 kg/ha) and K (144.6 kg/ha). The ginger variety "Nadia" (a variety with 270–300 days maturity, slender rhizome with less fibre) was planted in an individual plot of 20 m^2 at the spacing of 25 x 20 cm. The uniform dose of fertilizer used was 80:50:100 (N-P-K kg/ha). A stock solution of the respective quantity of each herbicide was prepared separately, by dissolving in half a liter of water and made up to the required quantity of spray solution (spray volume) by adding water. The spray solution of 600 L/ha was applied with a knapsack sprayer by using a flat fan nozzle. Mulching was done by using leaf biomass 5 t/ha. The crop was raised as a rainfed crop. All the necessary cultural practices were carried out uniformly to bring the crop to maturity. Weeds were counted at 75 DAP using a quadrat of 0.25 square meters (0.5 x 0.5 m), and the data obtained were expressed as density (no./m^2). The percent composition of weed flora was estimated from a weedy check plot. To record weed biomass weeds were cut at ground level, sun-dried in a hot air oven at 70 °C for 48 hrs and then weighed. Plant height (cm) was determined by randomly picking ten plants from each plot at 180 DAP and averaged. The number of effective tillers was obtained by counting them inside a 1 m^2 quadrate from four distinct sites within each plot at 180 DAP and taking the average. Similarly, number of leaves per plant were measured at 180 DAP. For the statistical analysis weed density and biomass were converted to 1 m^2 and imposed square root transformation by using a formula before analysis. Economic analysis was carried out by including all the variable costs (rhizome, manure, chemicals, labour, mulch materials, *etc*.) and their respective units used during the experiment. The prevalent market price of the produce was considered to calculate gross and net returns and finally, the benefit-cost ratio, an indicative of gross return per rupee investment, was calculated as follows: B: C ratio = gross return/cost of cultivation.

Statistical analysis was done by adopting the appropriate method of analysis of variance (Gomez and Gomez 1984) and mean comparisons were performed based on the least significant difference (LSD) at 0.05 probability.

Effect on weeds

All the integrated weed management treatments reduced the weed density and weed dry weight as compared to unweeded control in both the years at 75 DAP (**Table 1**). Unweeded control recorded significantly the highest number of weeds and dry

Table 1. Weed density, weed dry weight and weed control efficiency at 75 DAP of ginger as influenced by integrated weed management practices

Treatment	Weed density (no./m^2)		Weed dry weight (g/m^2)		Weed control efficiency (%)	
	2014	2015	2014	2015	2014	2015
Pendimethalin 1.5 kg/ha after planting but before mulching (20 DAP)	29.20	31.57	52.70	53.52	32.9	30.0
Oxyfluorfen 0.20 kg/ha after planting but before mulching (20 DAP)	30.60	32.35	55.40	56.48	29.4	26.1
Pendimethalin 1.5 kg/ha *fb* hand weeding (after planting but before mulching (20 DAP) *fb* 30-35 DAP)	20.40	18.89	37.60	38.62	52.1	49.5
Oxyfluorfen 0.20 kg/ha *fb* hand weeding (after planting but before mulching (20 DAP) *fb* 30-35 DAP)	20.70	19.73	38.80	39.37	50.6	48.5
Glyphosate 0.80 kg/ha (just before emergence of sprouts of ginger 25 DAP)	25.80	27.21	45.40	44.48	42.2	41.8
Glyphosate 0.80 kg/ha + pendimethalin 1.5 kg/ha (just before emergence of sprouts of ginger 25 DAP)	12.60	13.21	22.80	23.05	71.0	69.8
Glyphosate 0.80 kg/ha + oxyfluorfen 0.20 kg/ha (just before emergence of sprouts of ginger (\25 DAP)	11.40	12.46	21.40	22.12	72.7	71.1
Hand weeding (twice at 30 and 60 DAP)	6.20	7.38	11.80	10.23	85.0	86.6
Unweeded control	42.40	45.15	78.50	76.46	-	-
LSD (p=0.05)	4.20	2.62	5.26	3.22	-	-

DAP: Days after planting

matter of weeds than all other treatments. Hand weeding twice at 30 and 60 DAP recorded the lowest weed density 6.20 and 7.38/m^2 and dry weight of weeds 11.80 and 10.23 g/m^2, which was statistically at par with glyphosate 0.80 kg/ha + pendimethalin 1.5 kg/ha (just before emergence of sprouts of ginger (25 DAP) and glyphosate 0.80 kg/ha + oxyfluorfen 0.20 kg/ha (just before emergence of sprouts of ginger 25 DAP) and significantly superior over rest of the treatments in both the, respectively. The weed dry matter was 72.8% and 71.1% in 2014 and 2015, respectively which was lower in both years with the application of glyphosate 0.80 kg/ha + oxyfluorofen 0.2 kg/ha (before emegence of sprouts of ginger) than the unweeded control. This might be due to the application of pre-emergence herbicide, which effectively hindered the germination of weed seeds or hand weeding at 30 and 60 DAP and effectively controlled the latter emerged weeds. Moreover, Sathya Priya *et al*. (2013) recorded lesser weed density and dry weight with pre-emergence application of oxyfluorfen 200 g/ha in onion.

Weed control efficiency (WCE) denotes the magnitude of increase in yield due to weed control. In both years, the highest WCE (85.0%, 86.6%) were recorded in the plots receiving 2 hand weeding (30 and 60 DAP) which was closely followed by glyphosate 0.80 kg/ha + pendimethalin 1.5 kg/ha (just before emergence of sprouts of ginger (25 DAP)) (71.0%, 69.9%) and glyphosate 0.80 kg/ha + oxyfluorfen 0.20 kg/ha (just before emergence of sprouts of ginger 25 DAP) (72.7%, 71.1%), respectively. The lowest WCE was recorded in weedy check plots. The results confirmed the findings of Channappagouder and Biradar (2007) and Sampat *et al.* (2014).

Effect on ginger

The main growth contributing factors, *viz.* plant height, number of leaves per plant and number of tilers per plant were significantly influenced by different weed control treatments (**Table 2**). Among the treatments, unweeded control recorded significantly lower plant height, number of tilers per plant, and number of leaves per plant due to weed competition. Hand weeding twice at 30 and 60 DAP showed maximum plant height 56.5 and 57.5 cm and number leaves per plant 23.5 and 24.2, which was statistically at par with glyphosate 0.80 kg/ha + pendimethalin 1.5 kg/ha (just before emergence of sprouts of ginger 25 DAP) and glyphosate 0.80 kg/ha + oxyfluorfen 0.20 kg/ha (just before emergence of sprouts of ginger 25 DAP) and significantly superior over rest of the treatments in both the years (2014 and 2015), respectively. A similar trend was followed in number of tillers per plant. In 2014 and 2015 in both years, the number of tillers/plant was recorded 45.0 and 57.4%, respectively which was higher over the application of glyphosate 0.80 kg/ha + oxyfluorfen 0.2 kg/ha (before emegence of sprouts of ginger) than the unweeded control. This was attributed to timely and effective control of weeds, which might have increased the availability of moisture, nutrients, and solar radiation to the ginger.

However, All the weed control treatments differed in influencing fresh rhizome yield of ginger. Hand weeding twice at 30 and 60 DAP recorded significantly higher rhizome yield 21.32 and 22.43 t/

Table 2. Effects of integrated weed management practices on growth attributes and yield of ginger

Treatment	Plant height (cm)		No. of tillers per plant		No. of leaves per plant		Rhizome yield (t/ha)	
	2014	2015	2014	2015	2014	2015	2014	2015
Pendimethalin 1.5 kg/ha after planting but before mulching (20 DAP)	51.7	52.0	24.2	24.0	19.2	20.2	15.75	16.89
Oxyfluorfen 0.20 kg/ha after planting but before mulching (20 DAP)	51.2	51.7	23.8	22.9	18.8	19.1	15.12	16.05
Pendimethalin 1.5 kg/ha *fb* hand weeding (after planting but before mulching (20 DAP) *fb* 30-35 DAP)	54.4	54.0	26.3	26.1	20.7	21.0	18.88	19.12
Oxyfluorfen 0.20 kg/ha *fb* hand weeding (after planting but before mulching (20 DAP) *fb* 30-35 DAP)	53.8	53.5	25.7	26.1	20.2	20.9	18.23	18.46
Glyphosate 0.80 kg/ha (just before emergence of sprouts of ginger 25 DAP)	53.2	53.0	24.7	24.1	19.6	20.1	16.92	17.08
Glyphosate 0.80 kg/ha + pendimethalin 1.5 kg/ha (just before emergence of sprouts of ginger 25 DAP)	55.9	55.7	29.6	30.1	22.1	23.0	20.32	19.95
Glyphosate 0.80 kg/ha + oxyfluorfen 0.20 kg/ha (just before emergence of sprouts of ginger 25 DAP)	56.1	56.1	30.2	31.3	22.8	23.5	20.85	21.32
Hand weeding (twice at 30 and 60 DAP)	56.5	57.5	31.5	32.5	23.5	24.2	21.32	22.43
Unweeded control	48.3	47.1	20.9	19.9	16.4	15.8	10.87	10.99
LSD (p=0.05)	3.3	3.4	2.6	3.1	3.1	3.1	3.18	3.67

DAP: Days after planting

ha, respectively. It was statistically at par with the remaining other weed control treatments (**Table 2**) during both years. Two hand weeding treatments provided the season-long weed-free conditions hence resulted in appreciably higher yield than other treatments. Moreover, the application of glyphosate 0.80 kg/ha + pendimethalin 1.5 kg/ha and glyphosate 0.80 kg/ha + oxyfluorfen 0.2 kg/ha both before emegence of sprouts of ginger was the next superior treatment with respect to rhizome yield, as they improved the rhizome yield to the tune of 86.9, 81.5 and 91.8, 93.9% over the control in both years in 2014 and 2015, respectively. These treatments kept the crop almost weed free up to 75 days which markedly reduced the competition for nutrients and other resources by weeds which ultimately reduced weed dry matter production and nutrient depletion. However, improved growth parameters might have helped the plant to produce more photosynthates and translocation towards the sink *i.e.* rhizome. This accumulation of photosynthates helped the plant to develop more mother, primary and secondary rhizomes which ultimatey led to higher rhizome yield. The results were in agreement with those of Barooah *et al.* (2010) and Eshetu and Addisu (2015) who also obtained better crop growth and higher yield of ginger through effective weed control.

The rhizome yield of ginger was negatively associated with weed population (r = -0.986, -0.979) and weed dry weight (r = - 0.988, -0.973); during the year 2014 and 2015 respectively. Irrespective of species, with every one weed/m^2 increase in population of weeds, ginger rhizome yield would be expected to fall by 0.293, 0.275 t/ha (Y= 24.073 – 0.293x, R^2= 0.973, Y= 24.401 – 0.275x, R^2= 0.958). Similarly, every g/m^2 increase in biomass of weeds would result in 0.161, 0.162 t/ha loss in rhizome yield of ginger (Y= 24.112 – 0.161x, R^2= 0.977, Y= 24.577 – 0.162x, R^2= 0.948). Weed control efficiency of ginger followed the linear relationship with rhizome yield during both years respectively (R^2 = 0.9662 and 0.9514, **Figure 1a and b**).

Economics

The economic parameters largely depend on the economic yield of crop and production cos. The hand weeding twice at 30 and 60 DAP recorded the highest gross returns (₹ 2,24,320) and net returns of ₹ 1,12,230, which was followed by pendimethalin 1.5

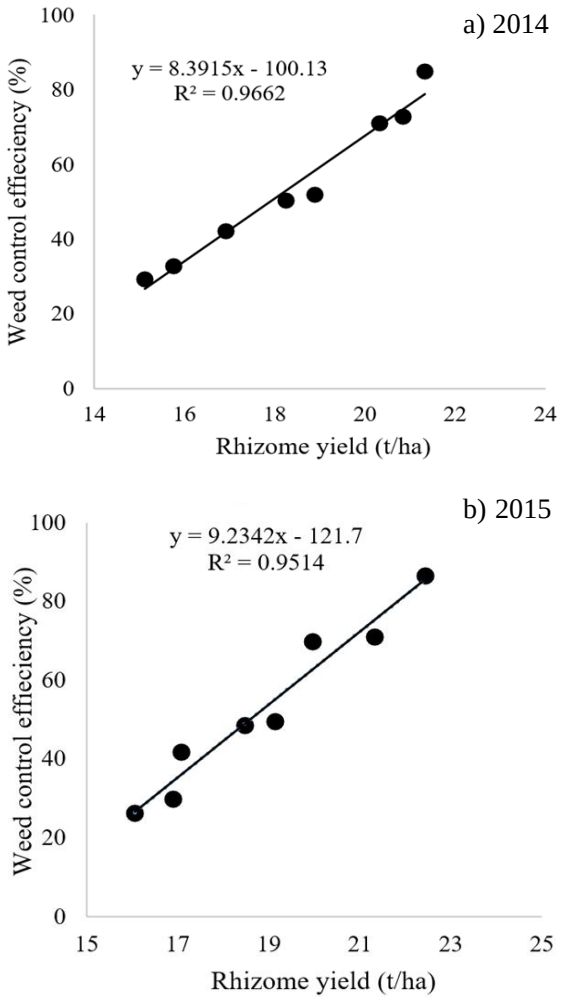

Figure 1. The relationship between weed control efficiency and rhizome yield of ginger as influenced by integrated weed management practices

Table 3. Economics as influenced by integrated weed management practices in ginger

Treatment	Gross returns (x10^3 ₹/ha)	Net returns (x10^3 ₹/ha)	B:C
Pendimethalin 1.5 kg/ha after planting but before mulching (20 DAP)	168.90	66.46	1.65
Oxyfluorfen 0.20 kg/ha after planting but before mulching (20 DAP)	160.50	58.50	1.57
Pendimethalin 1.5 kg/ha *fb* hand weeding (after planting but before mulching (20 DAP) *fb* 30-35 DAP)	191.20	82.76	1.76
Oxyfluorfen 0.20 kg/ha *fb* hand weeding (after planting but before mulching (20 DAP) *fb* 30-35 DAP)	184.60	76.60	1.71
Glyphosate 0.80 kg/ha (just before emergence of sprouts of ginger 25 DAP)	170.80	70.00	1.69
Glyphosate 0.80 kg/ha + pendimethalin 1.5 kg/ha (just before emergence of sprouts of ginger 25 DAP)	199.50	96.26	1.93
Glyphosate 0.80 kg/ha + oxyfluorfen 0.20 kg/ha (just before emergence of sprouts of ginger 25 DAP)	213.20	110.40	2.07
Hand weeding (twice at 30 and 60 DAP)	224.32	112.32	2.00
Unweeded control	109.93	9.93	1.10
LSD (p=0.05)	36.32	36.32	-

kg/ha *fb* hand weeding (after planting but before mulching (20 DAP) *fb* 30-35 DAP), glyphosate 0.80 kg/ha + oxyfluorfen 0.20 kg/ha (just before emergence of sprouts of ginger 25 DAP) and the lowest net returns obtained with unweeded control with net loss of ₹ 1,02,387 after two years of experiment. The net returns with the combined application of glyphosate 0.80 kg/ha + oxyfluorfen 0.2 kg/ha as 88.71% and 57.71% was higher as compared to application of oxyfluorfen 0.20 kg/ha after planting but before mulching and glyphosate 0.80 kg/ha before emergence of sprouts of ginger respectively (**Table 3**). But B:C was significantly higher (2.07) with application of glyphosate 0.80 kg/ha + oxyfluorfen 0.2 kg/ha. In hand weeded plots, the cost of cultivation increased remarkably due to higher labour wages. It increased the cost of manual weeding corresponding to total output cost. Higher profit due to chemical control in ginger have been supported by Barooah *et al.* (2010) and Sachdeva *et al*. (2015). The study demonstrated that two hand weeding at 30 and 60 DAP or application of glyphosate 0.80 kg/ha + oxyfluorfen 0.2 kg/ha is better options to manage weeds and improve rhizome productivity of ginger under rainfed ecosystem of middle Indo-Gangetic plains.

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