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INFLUENCE OF DIFFERENT WEED CONTROL METHODS ON WEED DENSITY AND RELATIVE IMPORTANCE VALUE OF WEEDS IN MANGO GINGER (*CURCUMA AMADA* ROXB.)

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Abstract

Field trials were conducted in the early cropping seasons of 2016 and 2017 at the Teaching and Research Farm of the Federal University of Agriculture Abeokuta (07° 20′N , 3° 23′E 159 m above sea level) in a derive savannah agro ecology region of South-western Nigeria to evaluate the effect of weed control methods on weed density and weed species composition in mango ginger. Ten weed control methods were evaluated and laid out in a randomized complete block design with three replications. Data collected on weed density were subjected to analysis of variance (ANOVA) and treatment means separated using 5% least significant difference (LSD at $p \leq 0.05$). Data collected on weed species composition were used to compute relative importance value (RIV). At 8 WAP, there was 48.51 to 96.55% reduction in weed density relative to the maximum on the weedy check plots as a result of different weed control methods. At 24 WAP, there was 34.48% to 55.17% reduction in number of weed species relative to the maximum on the weedy check plots as a result of different weed control methods. Our findings revealed reduction in the dominance of *Chromolaena odorata, Commelina benghalensis, Mariscus alternifolius, Passiflora foetida, Perotis indica* and *Triumpheta cordifolia* with the use of oxyfluorfen (oxy) as pre-emergence herbicide. However, further research is needed to prevent the dominance of *Panicum maximum* in mango ginger.

Keyword: dominance, herbicide, oxyfluorfen, pre-emergence, weed density, weed species, mango ginger

INTRODUCTION

Mango ginger (*Curcuma amada* Roxb.) is a plant belonging to ginger family, Zingiberaceae and in resemblance, closely related to turmeric (*Curcuma longa*). It originated from East India and occurs in the wild in parts of Bengal, Konkan and Madras (Chandarana *et al.*, 2005). The rhizomes of mango ginger look like that of ginger (*Zingiber officinale*) but have a raw mango aroma and taste (Alapati *et al.,* 1989). Mango ginger is typically grown as a rainfed crop, with ideal rainfall ranging from moderate to heavy. It grows best in humus-rich, well-drained sandy, clay loam soil and susceptible to water logging. Mango ginger is a spice crop of great importance around the world. It is a valuable cash crop and plays a significant role because of its peculiar raw mango-like aroma and flavour which is highly valued in salad, culinary preparations and pickles in south India and chutneys in north India (Nayak, 2002; Sasikumar, 2005; Tepe *et al.,* 2006). Mango ginger is used medicinally as a coolant, aromatic and astringent and to promote digestion. A rhizome paste has traditionally been used for healing of wounds, cuts and itching (Srivastava *et al.,* 2006). The aqueous and organic solvent extracts of mango ginger are antibacterial against *Escherichia coli*, *Bacillus subtilis* and *Staphylococcus aureus* (Chandarana *et al.*, 2005).

Weeds are unwanted plants that interfere with cropping activities. These plants have specific characteristics that make them more competitive under a wide range of environmental and climatic conditions (Labrada and Parker, 1994).

Ginger crop is highly susceptible to weed competition especially at the initial stages of crop growth. In most cases weed management accounts for the major share of the total cost of cultivation (KAU, 2006). Akobundu (1987) reported that weeds result in 65% reduction in yield of root and tuber crops and takes 25% of total labour use in production. Osunleti *et al.* (2021) reported 92.2% yield loss in mango ginger due to uncontrolled weed growth.

(KAU, 2006) indicated that 30–45% yield reduction in ginger may occur due to uncontrolled weed growth. Ratnam *et al.* (2012) reported 80% rhizome yield reduction in turmeric due to uncontrolled weed growth. Kaur *et al.* (2008) reported that losses in turmeric rhizome yield due to weeds varied from 63.9 to 76.5%. Similarly, Krishnamurthi and Ayyaswamy (2000) observed that yield losses of turmeric due to weeds vary from 30–75%. The present study hypothesized that different weed control methods had different effect on weed density and composition. Therefore, the aim of this study is to evaluate the effect of different weed control methods of weed density and composition.

MATERIALS AND METHODS

The field trials were conducted in the early cropping seasons of 2016 and 2017 on the Teaching and Research Farm Directorate of the Federal University of Agriculture, Abeokuta, Nigeria in the forest savannah transition agroecological zone (7^0, 20'N, 3^0, 23'E). The details of physic-chemical properties of the soil prior the commencement of the trials are contained in Tab. I. The result of the analysis indicated that the soil was sandy loam in texture in both years with soil pH of 6.48 and 6.60 in 2016 and 2017, respectively (Tab. I). The site received a total rain fall of 1146.3 mm and 839.7 mm in 2016 and 2017, respectively. The mean temperature

I: *Physic-chemical properties of soil at the experimental sites*

Soil Composition	2016	2017
pH	6.48	6.60
Particle size analysis		
Sand (g/kg)	799.5	736.6
Silt (g/kg)	160.5	220.5
Clay (g/kg)	40.0	42.9
Textural class	sandy loam	sandy loam
Chemical composition		
Organic carbon (%)	1.56	1.92
Available P (mg/kg)	2.46	4.05
Total N (%)	0.11	0.13
Exchangeable Cations (centimol/kg)		
Ca	6.64	6.59
Na	0.22	0.16
Mg	1.25	0.18
K	0.31	0.45

II: *Monthly distribution and annual total rainfall, mean temperature and relative humidity to the experimental site, 2016 and 2017*

Month	2016			2017		
	Total rainfall (mm)	Mean temperature (°C)	Relative Humidity (%)	Total rainfall (mm)	Mean temperature (°C)	Relative Humidity (%)
January	32.0	28.1	56.2	15.9	28.9	69.5
February	0.0	30.3	56.7	0.0	30.2	70.7
March	150.3	29.5	59.1	34.3	30.0	68.1
April	68.2	29.2	63.1	112.8	29.1	73.8
May	226.2	29.0	73.6	146	27.8	80.8
June	150.5	26.7	72	111	26.7	80.8
July	65.2	26.3	72.7	156	25.7	85.5
August	63.6	25.7	72.8	90.0	25.5	81
September	229.0	26.9	68.9	52.0	25.2	77.3
October	155.4	28.0	65.3	90.2	27.6	82.2
November	5.9	22.5	65.3	45.6	28.6	75.5
December	0.0	28.1	56.6	15.9	28.9	77.3
Mean		27.5	56.2		27.9	69.5
Total	1146.3			839.7		

(27.5 °C and 27.9 °C) and relative humidity (56.2% and 69.5%) are recorded respectively during 2016 and 2017 cropping seasons (Tab. II).

In both years, ten treatments consisting of pre emergence application of oxyfluorfen (24% EC) at 0.36 kg a.iha^{-1} (T_1), pre emergence application of oxyfluorfen at 0.36 kg a.iha^{-1} + post emergence application of oxyfluorfen at 0.24 kg a.iha^{-1} (T_2), pre emergence application of oxyfluorfen at 0.36 kg a.iha^{-1} + hoe weeding (T_3), pre emergence application of oxyfluorfen at 0.24 kg a.iha^{-1} (T_4), pre emergence application of oxyfluorfen at 0.24 kg a.iha^{-1} + post emergence application of oxyfluorfen at 0.24 kg a.iha^{-1} (T_5), pre emergence application of oxyfluorfen at 0.24 kg a.iha^{-1} + hoe weeding (T_6), hoe weeding at 4, 8, 12 weeks after planting (T_7), hoe weeding at 4, 8, 12, 16 weeks after planting (T_8), hoe weeding at 4, 8, 12, 16, 20 weeks after planting (T_9) and weedy check (T_{10}) were imposed for weed control in mango ginger. The post emergence treatments were applied at 8 weeks after planting (WAP). Herbicides were applied with knapsack sprayer fitted with flat-fan nozzle using 250 litres water/ha. The treatments were arranged in a randomized complete block design and replicated three times. In each year, the field was ploughed and harrowed at two-week intervals to ensure a tilth weed-free soil. After the removal of weed stumps and debris, field layout was done and beds of 3 m × 3 m were made manually with hoe. Mango ginger rhizome one per hole were planted per stand at 0.20 m × 0.20 m to give total plant population of 250,000 plants ha^{-1}. The weeding operations were preceded by collection of weed samples using systematic random sampling on the plots. Weed samples were collected from quadrat size of 0.5 m × 0.5 m (two quadrats per plot) before every weeding according to the treatments. Weed samples within 0.5 m^2 quadrat were uprooted, sorted into different weed types (grasses, broadleaves and sedges) and identified to species level using a Handbook of West African Weeds (Akobundu and Agyakwa, 1998) and counted. The weed samples collected were pooled together and counted to get the total weed count.

Data collected on weed count for the two years were pooled and subjected to analysis of variance (ANOVA) using Genstat 12th edition to determine the level of significance of the treatments. Treatment means were separated using 5% least significant difference (LSD). Data collected on weed species composition were subjected to quantitative analysis to compute Relative Frequency, Relative Density and Relative Importance Value using the formulae below according to DAS 2011:

i) Relative Density (RD) =

$$= \frac{\text{Density of a particular species} \times 100}{\text{Total densities of all species}},$$

ii) Relative Frequency (RF) =

$$= \frac{\text{Frequency of a particular species} \times 100}{\text{Total frequencies of all species}},$$

iii) Relative Importance Value =

$$= \frac{\text{Relative frequency} + \text{Relative weed density}}{2}.$$

RESULTS

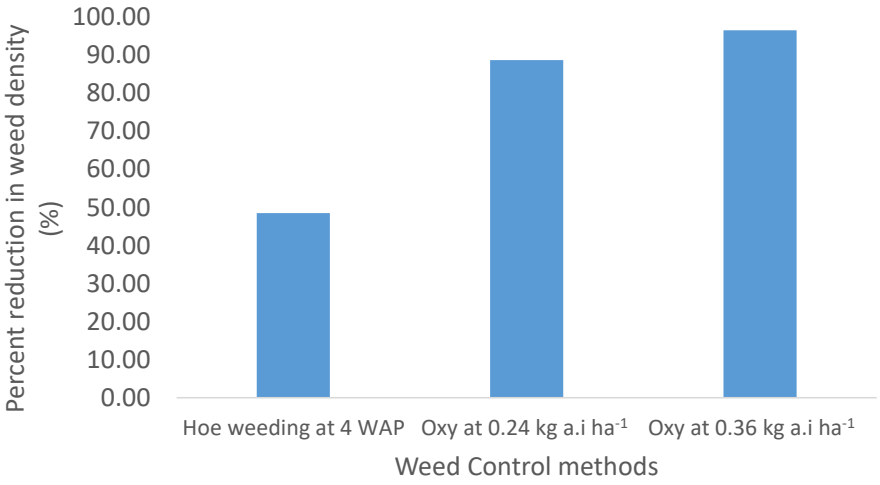
Effect of Weed Control Methods on Weed Density

Weed control methods had significant effect on density of different types of weed and total weed density at 8 and 24 WAP (Tabs. III and IV). At 8 WAP the highest weed count for different types of weeds and their total was recorded on the weedy check plots (Tab. III). Application of pre-emergence herbicide irrespective of rates and post emergence treatments resulted in the lowest broadleaf, grass and total weed count compared with the hoe-weeding regime and weedy check. At 8 WAP, there was 48.51 to 96.55% reduction in weed density relative to the maximum on the weedy check plots as a result of different weed control methods (Fig. 1).

Also at 24 WAP the highest weed density for different classes of weeds and their total was recorded on the weedy check plots (Tab. IV). Application of each of oxyfluorfen at 0.36 kg a.i ha^{-1} and oxyfluorfen at 0.24 kg a.i ha^{-1} as pre emergence herbicide followed by oxyfluorfen at 0.24 kg a.i ha^{-1} and hoe weeding as post emergence treatment resulted in the lowest broadleaf, grass and total weed density similar to those weeded at 4, 8, 12, 16,

III: *Effect of weed control methods on weed density at 8 WAP*

Weed Count per meter square at 8 WAP				
Treatments	Broadleaf	Grasses	Sedge	Total
T_1	2.3	2.0	0.0	4.3
T_2	2.3	3.0	0.0	5.3
T_3	1.7	2.3	0.0	4.0
T_4	6.0	7.3	0.7	14.0
T_5	6.3	10.3	0.0	16.7
T_6	5.0	8.3	0.0	13.3
T_7	37.0	30.7	2.8	70.5
T_8	38.0	27.7	1.7	67.3
T_9	34.3	26.7	2.8	63.8
T_{10}	75.3	47.0	8.2	130.5
LSD	9.388	7.813	2.06	16.66
p value	p = 0.001	p = 0.001	p = 0.001	p = 0.001



1: *Reduction of total weed density relative to the weedy check at 8 WAP*

20 WAP (Tab. IV). Hoe weeding at 4, 8, 12, 16 WAP resulted in significantly lower broadleaf, grasses and total weed density than the pre emergence application of oxyfluorfen at 0.36 kg a.i ha^{-1} and oxyfluorfen at 0.24 kg a.i ha^{-1} (Tab. IV).

IV: *Effect of weed control methods on weed count at 24 WAP*

Weed Count per meter square at 24 WAP				
Treatments	Broadleaf	Grasses	Sedge	Total
T_1	48.0	40.0	12.5	100.5
T_2	12.0	8.5	4.0	24.5
T_3	8.5	11.0	6.0	25.5
T_4	55.5	49.5	14.5	119.5
T_5	13.0	10.0	7.0	30.0
T_6	11.0	11.0	8.5	30.5
T_7	48.5	36.5	10.0	95.0
T_8	29.5	23.5	7.5	60.5
T_9	16.0	14.0	4.0	34.0
T_{10}	83.0	57.5	19.0	159.5
LSD	12.26	5.522	5.514	15.54
p value	p = 0.001	p = 0.001	p = 0.003	p = 0.001

Effect of Weed Control Methods on Relative Importance Value of Weeds in Mango Ginger

At 8 WAP in 2016, *Spigelia anthelmia* had the highest RIVof 58.33% on plots with application of oxyfluorfen at 0.36 kg a.i ha^{-1} as pre emergence and hoe weeding as post emergence treatments (Tab. V). Across the weed control methods, *Spigelia anthelmia, Digitaria horizontalis* and *Panicum maximum*had RIV greater than 5%. Conversely, *Commelina benghalensis, Ipomoea triloba, Perotis indica,* and *Physalis angulata*had RIV less than 5% irrespective of weed control methods. There was total weed control of *Commelina benghalensis, Cyperus rotundus, Tridax procumens* and *Triumpheta cordifolia* on plots treated with pre emergence herbicide irrespective of rates and post emergence treatments (Tab. V). There was 40.00% to 75.53% reduction in number of weed species relative to the maximum on the weedy check plots as a result of different weed control methods (Fig. 2).

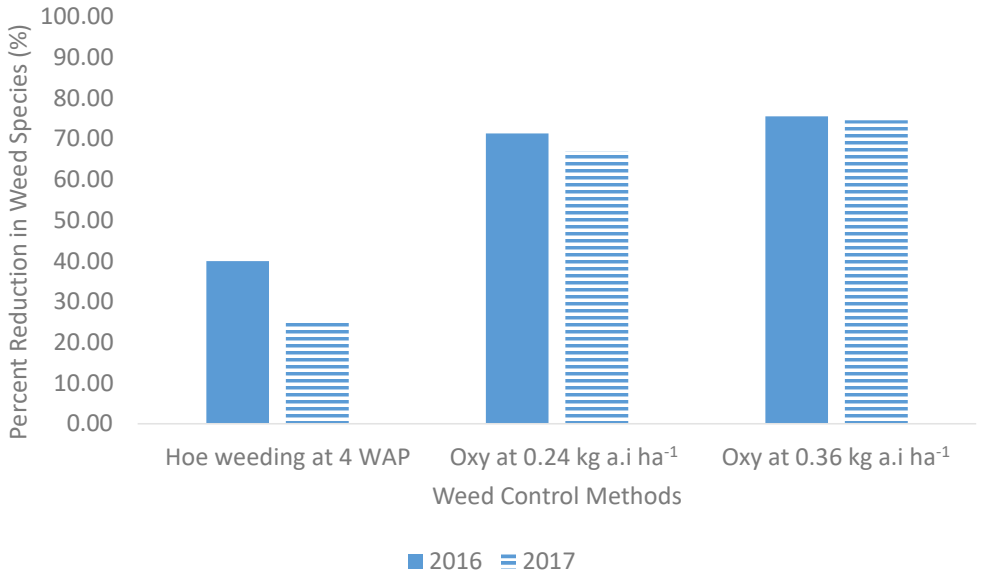
Similarly at 8 WAP in 2017, *Spigelia anthelmia* had the highest RIV of 58.33% on plots with application of oxyfluorfen at 0.36 kg a.i ha^{-1} as pre emergence and hoe weeding as post emergence treatments (Tab. VI). Across the weed control methods, *Imperata cylindrica, Panicum maximum* and *Tridax procumens* had RIV greater than 5%. Conversely, *Commelina benghalensis,* and *Passiflora foetida* had RIV less than 5% irrespective of weed control methods. There was total weed control of *Chromolaena odorata, Commelina benghalensis, Paspalum scrobiculatum, Passiflora foetida* and *Triumpheta cordifolia* on plots treated with pre emergence herbicide irrespective of rates and post emergence treatments (Tab. VI). Also, there was total weed control of *Brachiaria deflexa* with the application of oxyfluorfen at 0.36 kg a.iha^{-1}. There was 25.38% to 74.62% reduction in number of weed species relative to the maximum on the weedy check plots as a result of different weed control methods (Fig. 2).

At 24 WAP in 2016, *Spigelia anthelmia* and *Digitaria horizontalis* had the highest RIV of 24.71% each on plots hoe weeded for 4, 8, 12, 16, 20 WAP, and irrespective of weed control methods, *Digitaria horizontalis* and *Panicum maximum* had RIV greater than 5% (Tab. VII). With further weed control measure at 8 WAP on herbicide treated plots and hoe weeded plots, there was total weed control of *Commelina benghalensis.* Furthermore, across the weed control methods, there was total weed control of *Triumpheta cordifolia* (Tab. VII).

At 24 WAP in 2017, *Spigelia anthelmia* had the highest RIV of 29.29% on plot treated with

V: *Effect of weed control methods on Relative Importance Value at 8 WAP in 2016*

Weed Species	Weed Control Methods (%)									
	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	T_9	T_{10}
Brachiaria deflexa	0.00	0.00	0.00	11.25	11.56	10.56	6.00	2.91	3.49	3.92
Chromolaena odorata	0.00	0.00	0.00	0.00	0.00	0.00	15.50	14.51	13.81	9.10
Commelina benghalensis	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.43	2.94	3.92
Cyperus rotundus	0.00	0.00	0.00	0.00	0.00	0.00	3.50	3.43	4.05	6.01
Digitaria horizontalis	33.33	18.33	20.83	25.63	44.67	44.17	21.50	22.41	23.25	15.03
Imperata cylindrical	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	5.49
Ipomoea triloba	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.57
Mariscus alternifolius	0.00	0.00	0.00	0.00	0.00	0.00	7.00	5.81	6.43	6.52
Panicum maximum	16.67	18.33	20.83	16.25	17.11	18.61	14.50	13.46	12.70	7.04
Passiflora foetida	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	5.49
Perotis indica	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.15
Physalis angulate	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.35
Spigelia anthelmia	33.33	45.00	58.33	27.50	26.67	26.67	19.50	18.72	17.70	16.06
Tridax procumens	16.67	18.33	0.00	19.38	0.00	0.00	12.50	11.88	12.70	8.84
Triumpheta cordifolia	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.43	2.94	5.49



2: *Reduction in number weed species relative to the weedy check at 8 WAP*

oxyfluorfen at 0.36 kg a.i ha^{-1} as pre emergence plus oxyfluorfen at 0.24 kg a.i ha^{-1} as post emergence treatment (Tab. VIII). Irrespective of weed control methods, *Imperata cylindrica, Panicum maximum, Spigelia anthelmia* and *Tridax procumens* had RIV greater than 5%. Conversely, *Perotis indica* had RIV less than 5% irrespective of weed control methods. With further weed control measure at 8 WAP on herbicide treated plots and hoe weeded plots, there was total weed control of *Commelina benghalensis, Paspalum scrobiculatum* and *Passiflora foetida,* while *Chromolaena odorata* was totally controlled with further weed control measures at 8 WAP on herbicide treated plots. Furthermore across the weed control methods, there was total weed control of *Triumpheta cordifolia* (Tab. VIII).

In both years at 24 WAP, application of pre emergence herbicide alone irrespective of the rate of application resulted in 36.21% reduction in number of weed species relative to the maximum on the weedy check plots (Fig. 3). There was an additional 18.97% reduction in number of weed species when pre-emergence herbicide was followed up with a post emergence treatment. Also

VI: *Effect of weed control methods on Relative Importance Value at 8 WAP in 2017*

Weed Species	Weed Control Methods (%)									
	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	T_9	T_{10}
Brachiaria deflexa	0.00	0.00	0.00	10.31	11.32	10.56	6.49	3.74	4.74	4.36
Chromolaena odorata	0.00	0.00	0.00	0.00	0.00	0.00	16.19	14.42	15.16	9.15
Commelina benghalensis	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.29	3.32	4.13
Cyperus rotundus	0.00	0.00	0.00	8.39	0.00	0.00	6.06	3.29	3.80	5.31
Imperata cylindrical	22.50	15.48	20.83	21.33	16.88	18.61	14.90	13.51	13.27	9.63
Mariscus alternifolius	0.00	0.00	0.00	0.00	0.00	0.00	4.11	5.67	6.65	6.78
Panicum maximum	38.75	38.10	58.33	25.17	26.28	26.67	18.35	18.05	17.05	15.55
Paspalum scrobiculatum	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	5.83
Passiflora foetida	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.42
Perotis indica	0.00	0.00	0.00	0.00	0.00	0.00	3.24	0.00	0.00	6.07
Senna occidentalis	0.00	15.48	0.00	0.00	0.00	0.00	11.45	12.14	11.86	8.91
Tridax procumens	38.75	30.95	20.83	34.79	45.51	44.17	19.21	22.60	20.82	14.84
Triumpheta cordifolia	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.29	3.32	7.02

VII: *Effect of weed control methods on Relative Importance Value at 24 WAP in 2016*

Weed Species	Weed Control Methods (%)									
	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	T_9	T_{10}
Brachiaria deflexa	0.00	20.20	14.22	8.38	7.20	12.86	6.19	5.06	0.00	5.58
Chromolaena odorata	0.00	16.50	0.00	6.50	18.94	14.29	12.67	14.61	7.94	9.82
Commelina benghalensis	10.72	0.00	0.00	7.63	0.00	0.00	0.00	0.00	0.00	2.65
Cyperus rotundus	10.27	0.00	7.11	10.64	15.91	12.86	8.97	5.06	0.00	8.40
Digitaria horizontalis	18.38	11.95	21.57	14.40	20.45	12.86	18.69	17.59	24.71	14.62
Imperata cylindrical	5.59	0.00	0.00	8.76	0.00	5.00	4.02	5.06	10.88	2.37
Ipomoea triloba	0.00	0.00	0.00	6.50	0.00	0.00	0.00	0.00	0.00	0.00
Mariscus alternifolius	11.62	14.65	17.16	0.00	12.88	17.14	8.04	10.29	9.41	7.84
Panicum maximum	13.42	8.25	8.58	12.52	8.71	14.29	9.43	11.62	6.47	10.10
Passiflora foetida	0.00	6.40	0.00	0.00	0.00	0.00	0.00	0.00	0.00	5.58
Perotis indica	0.00	0.00	5.64	0.00	0.00	0.00	7.12	0.00	0.00	2.65
Physalis angulate	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.65
Spigelia anthelmia	14.77	10.10	18.63	13.27	15.91	0.00	15.91	21.32	24.71	12.36
Tridax procumbens	15.23	11.95	7.11	11.39	0.00	10.71	8.97	9.38	15.88	9.25
Triumpheta cordifolia	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	6.14

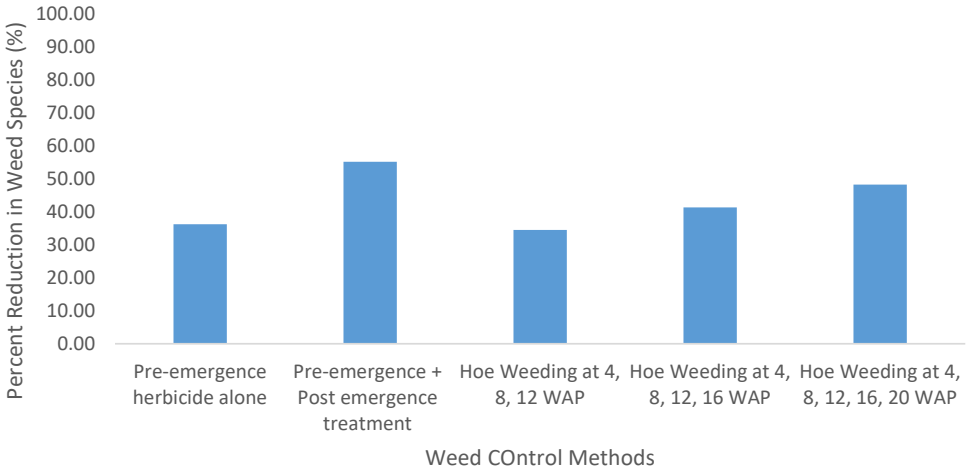
on hoe weeded plots, there was increase in percent weed species reduction from 34.48–48.28% as number of hoe weeding increases (Fig. 3).

DISCUSSION

The lower weed density and number of weed species on hoe weeded plots at 8 WAP compared to the weedy check was as a result of hoe weeding done on the plots at 4 WAP which helped to remove the first flush of weeds that sprang up immediately after planting. This result corroborates the report of Sah *et al.* (2017) who reported that hand weeding reduced weed dry matter production in ginger. Also, the lower weed count and number of weed species at 8 WAP on the herbicide treated plots compared to the hoe weeded plot and the weedy check was as a result of the pre emergence herbicide applied at planting. The herbicide applied at planting killed the emerging weeds from the soil thereby reducing the number of weeds on

VIII: *Effect of weed control methods on relative importance value at 24 WAP in 2017*

Weed Species	Weed Control Methods (%)									
	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	T_9	T_{10}
Brachiaria deflexa	0.00	0.00	0.00	4.39	10.56	8.85	7.10	0.00	0.00	2.55
Chromolaena odorata	0.00	0.00	0.00	8.30	0.00	0.00	14.42	16.40	13.57	8.56
Commelina benghalensis	6.90	0.00	0.00	9.25	0.00	0.00	0.00	0.00	0.00	5.44
Cyperus rotundus	0.00	22.47	22.88	8.30	10.56	12.69	8.32	9.92	13.57	5.44
Imperata cylindrical	13.81	7.83	8.50	11.60	6.85	6.92	13.20	14.55	13.57	6.48
Mariscus alternifolius	6.90	0.00	0.00	8.30	10.56	8.85	4.16	4.50	5.32	5.44
Panicum maximum	16.03	20.20	25.82	11.13	15.56	19.62	15.64	21.03	20.93	16.90
Paspalum scrobiculatum	10.48	0.00	0.00	4.39	0.00	0.00	0.00	0.00	0.00	4.75
Passiflora foetida	11.03	0.00	0.00	10.66	0.00	0.00	0.00	0.00	0.00	4.40
Perotis indica	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.40
Senna occidentalis	0.00	0.00	0.00	0.00	0.00	0.00	8.32	5.42	5.32	7.52
Spigelia anthelmia	14.92	29.29	22.88	7.36	26.67	21.54	11.37	12.70	11.20	8.91
Tridax procumens	19.92	20.20	19.93	16.32	19.26	21.54	17.47	15.48	16.52	14.12
Triumpheta cordifolia	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	5.09



3: *Reduction in number weed species relative to the weedy check at 24 WAP in both years*

the treated plots. This is in agreement with earlier report of Channappagoudar *et al.* (2013); Sah *et al.* (2017) who observed higher total weed weight and count on untreated plots compared to treated plots in turmeric. Hill and Santlemann (1969) attributed lower weed weight on treated plots to rapid depletion of carbohydrate reserves of weeds through rapid respiration. Also, SathyaPriya *et al.*, (2013) recorded lesser weed density and dry weight with pre-emergence application of oxyfluorfen in onion. At 24 WAP, the lower weed count and species composition observed on plots with the application of pre and post emergence treatments compared to pre emergence herbicide alone confirms the need for additional control measure for effective weed control in season long crops such as mango ginger. Also, integrated weed management approach of pre emergence herbicide followed by hoe weeding gave better weed control than when plots were only hoe weeded at 4, 8, 12 WAP and up to 16 WAP. These results corroborates earlier report of Kaur *et al.* (2008, 2016) who reported effective and long-term control of weeds with integration of herbicide and straw mulch in turmeric. Sah *et al.* (2017) also reported lower weed density when each of pendimethalin and oxyfluorfen was follow up by hand weeding and mulch than when they are used alone for weed control in ginger.

Tridax procumbens a member of Asteraceae family consistently had RIV greater than 5% at 8 and 24 WAP in both years especially on the hoe weeded plots. The high RIV of *Tridax procumbens* could be attributed to high prolificacy and plasticity in seed production as well as the ability to adapt to low

soil moisture. This observation agrees with earlier report of Olorunmaiye *et al.* (2011) who suggested high colonizing power of the family Asteraceae, to the efficient dispersal of seeds. Oluwatobi and Olorunmaiye (2014) also attributed the high relative weed density observed in members of Asteraceae to their aggressive growth, short life cycle, and large seed production.

In 2016, *Digitaria horizontalis* a member of Poaceae family had very high RIV both initially at 8 WAP and later in crop life cycle at 24 WAP. The high RIV which is a function of its occurrence and abundance could be attributed to its aggressive growth pattern and ability to cover the ground in the shortest possible time. This observation agrees with earlier report of Amorim da Silva *et al.* (2018) who reported *Digitaria horizontalis* to be aggressive with high power of dispersal and difficult to control in various cultures. Lym and Travnicek (2015), also reported most species of the Poaceae family to be troublesome and difficult to control.

Panicum maximum consistently had RIV greater than 5% throughout the experiment and in both years which is an indication of its high occurrence and abundance than other weeds, hence its dominance. The high dominance of *Panicum maximum* could be attributed to perennating organ possessed by the weed which helps its persistence and survival across seasons and years even during drought. This results corroborates with that of Njarui *et al.* (2015), who reported good persistence of *Panicum maximum* and their tolerance to low rainfall and drought stress environments. De Lima Veras *et al.* (2020), and Gurgel *et al.* (2020), also reported *Panicum maximum* to have high persistence and productivity due to its high photosynthetic and water efficiency, it is also highly adaptable to different climate conditions and poor soils.

CONCLUSION

In this study, different weed control methods reduced weed density and number of weed species initially at 8 WAP and later at 24 WAP. Initially at 8 WAP, there was 48.51% and 25.38% to 40.00% reduction in weed density and weed species number, respectively as a result of hoe weeding at 4 weeks after planting. Also, with pre emergence herbicide application, there was 88.74% to 96.55% and 66.92% to 75.53% reduction in weed density and weed species composition, respectively relative to the weedy check. Therefore, for 50% or more reduction in weed density and weed species composition in mango ginger, pre emergence herbicide should be used at planting followed by a post treatment. However, where hoe-weeding is preferable and affordable, mango ginger should be weeded up to 20 WAP. Based on the results of our study, further research is needed to prevent the future dominance of weeds like *Digitaria horizontalis, Panicum maximum, Tridax procumbens, Spigelia anthelmia* in mango ginger where this herbicide is used at the same rates.

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