

Weed Management for Higher Productivity of Ginger (*Zingiber officinale*) in Plains of Assam

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Authors' contributions

This work was carried out in collaboration between both the authors. Author JD designed the study, supported and guided during the entire experimentation period and reviewed the draft of the manuscript. Author AB supervised the field activities, performed the statistical analysis and wrote the first draft of the manuscript. Both the authors read and approved the final manuscript.

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ABSTRACT

A field experiment was conducted in Instruction-cum-Research Farm of Assam Agricultural University, Jorhat district, Assam, India during 2014-15 and 2015-16 to identify a suitable combination of ginger and cowpea intercropping and weed management practice to effectively manage the weeds in ginger. A total of 16 numbers of treatment combinations were considered, comprising 4 legume inter-cropping systems and 4 weed management practices. Intercropping of legume crop Cowpea either in between rows of Ginger and incorporated at 40 days after sowing (DAS) or in between alternate rows of Ginger and incorporated at 40 days after sowing (DAS) and pre-emergence application of Metribuzin 500 g ai ha⁻¹ + hand weeding (HW) at 70, 100 and 140 days after planting (DAP) recorded better results in terms of ginger growth and rhizome yield.

Keywords: Inter-cropping; weed management; legume; cowpea; rhizome; ginger; pre-emergence.

1. INTRODUCTION

Spices are high value and export-oriented commodity crops which play an important role in

agricultural economy of the country Yadav et al., [1]. Among different spices, ginger is one of the most popular crops grown for its aromatic rhizome. It is either used directly in its raw form

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or is processed into different value-added products like candy, oil, flakes etc. Due to its antioxidant properties it also has the potential to treat numerous disorders Najim, [2]. In the global scenario, India ranks first in terms of ginger production. North-East India, accounts for 49 per cent of India's ginger area and 72 per cent of India's ginger production. Amongst the North-Eastern states, Assam has the highest acreage and production Rahman et al., [3]. But ginger cultivation in Assam is confined mostly to the hilly areas of Karbi Anglong district where farmers usually follow *Jhum* (Shifting) cultivation. However, no major breakthrough has been achieved in context of boosting the production and increasing export of ginger in the state.

Ginger being a widely spaced and long duration crop, provides an opportunity to the growers to utilize the available vacant space at the early stage of rhizome, to grow any short duration leguminous intercrop. This will further enhance the soil condition by nitrogen fixation, apart from additional income generation.

But if the available space is not managed well than weeds can act as a major production constrains of ginger, as the crop takes a longer time to establish. Thus, an early control of the weeds is very essential so that the weeds do not overpower the crop.

Thus, the field trial was proposed to study the effect of growing of a fast-growing legume intercrop like cowpea with ginger, combined with suitable weed management practice on growth and yield from ginger crop.

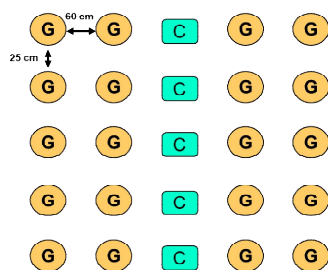
2. MATERIALS AND METHODS

The field experiment was conducted in Instruction-cum-Research Farm of Assam Agricultural University, Jorhat district, Assam, India. The experimental site of the farm is located at 26°47'N latitude, 94°13'E longitude and at an

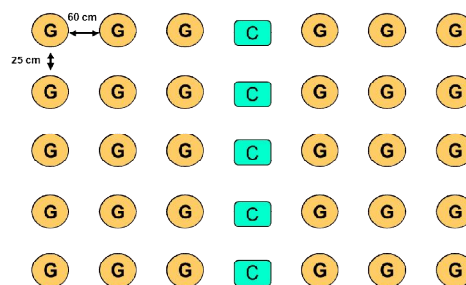
elevation of 86.56 meters above mean sea level. The experimental plots were prepared adequately and demarcated into 48 sub-plots each measuring 20 m² to accommodate 16 treatment combinations replicated 3 times which covered a net area of 960 m² and gross area 1482 m². Farm yard manure @ 10 t ha⁻¹ was applied during the time of bed preparation and recommended dose of N:P₂O₅:K₂O @ 75:50:50 kg ha⁻¹ in the form of urea (46% N), single super phosphate (16% P₂O₅) and muriate of potash (60% K₂O) were applied. Good quality rhizomes of *Nadia* variety of ginger were pre-treated with Mancozeb @ 3.0 g kg⁻¹ rhizome and planted in a spacing of 60 cm between two rows and 25 cm between rhizomes. Each ginger rhizome used for planting weighted approximately 40-50 grams. UPC-278, a fodder variety of cowpea was sown as an intercrop as per the treatment requirement and was uprooted and incorporated in the soil at 40th day after sowing. Ginger planting and Cowpea sowing were completed on the same.

There were total 16 treatment combinations comprising of 4 Legume Intercropping System viz., I₁: Ginger + Cowpea (2:1); Cowpea incorporated at 40 DAS, I₂:Ginger + Cowpea (3:1); Cowpea incorporated at 40 DAS, I₃: Cowpea in between rows of Ginger and incorporated at 40 DAS, I₄: Cowpea in between alternate rows of Ginger and incorporated at 40 DAS and 4 Weed Management Practices viz., W₁:Weedy (Control), W₂: Hand weeding at 40, 70, 100 and 140 DAP, W₃: Pre-emergence application of Oxadiargyl 90 g ai ha⁻¹ + hand weeding at 70, 100 and 140 DAP and W₄: Pre-emergence application of Metribuzin 500 g ai ha⁻¹ + hand weeding at 70, 100 and 140 DAP.

Legume crop cowpea was sown in between the rows of ginger, following different row proportions (2:1 and 3:1) and in additive series (in between ginger rows and in between alternate rows of ginger).



a) Ginger (G) + Cowpea (C) 2:1 row proportion



b) Ginger (G) + Cowpea (C) 3:1 row proportion

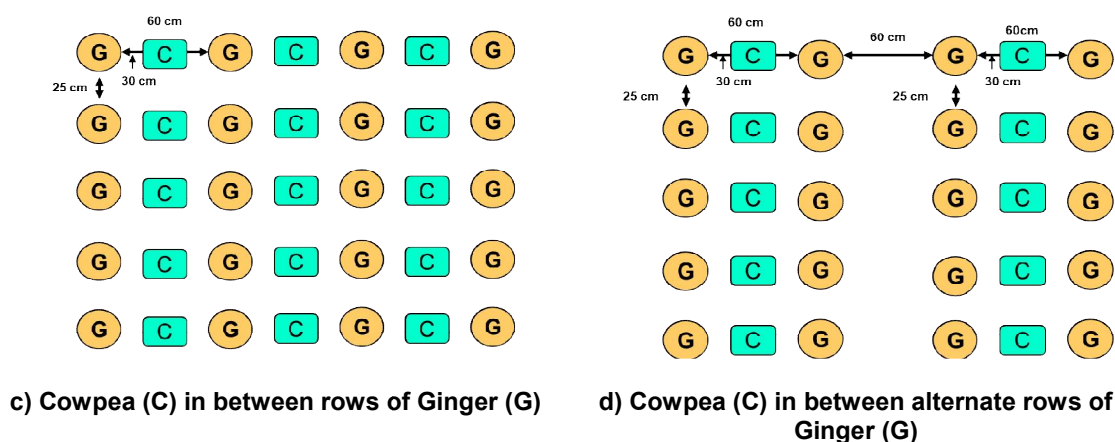


Fig. 1. Representative diagram of cowpea sowing and ginger planting pattern as followed in this experiment

Pre-emergence herbicides were applied with a spray volume of 500 L ha⁻¹ on the 3rd day after planting ginger. The plots were then mulched with rice straw @ 4 t ha⁻¹ in two splits, one immediately after planting of ginger and second at 70 DAP. Light earthing up was done at 60 and 100 DAP for ginger in all treated plots, except for weedy plots with no earthing up operations. Need based plant protection measures were adopted in ginger to manage pests and diseases as per package of practices recommended by Assam Agricultural University. Spraying of Mancozeb with alternate cycles of Streptomycin was initiated in the field before onset of monsoon to prevent fungal and bacterial infection.

In both the years, ginger crop was harvested on the 262nd day after planting. From each plot, ginger rhizome was harvested by digging out with the help of spade. Soil particles attached to it were removed and fresh weight was recorded for each plot.

All the data pertaining to the present investigation wherever needed were statistically analysed for Factorial Randomized Block Design (RBD) described by Panse and Sukhatme (1978). Critical differences (CD) at 5 per cent probability level was calculated only when the F value been found out to be significant.

3. RESULTS AND DISCUSSION

3.1 Length (cm) and Breadth of Ginger Rhizome

At all the considered time intervals of 100, 130 and 160 DAP, highest rhizome length of 13.7 cm,

18.9 cm and 21.0 cm, respectively in 2014-15 and 14.4 cm, 19.7 cm and 21.6 cm respectively, in 2015-16 was recorded in the treatment of Cowpea in between Ginger; incorporated 40 DAS, which was statically *at par* with the treatment Cowpea in alternate rows of Ginger; incorporated 40 DAS. A similar trend was recorded in terms of ginger rhizome breadth in both the years (2014-15 and 2015-16). Intercropping treatment of Cowpea in between Ginger; incorporated 40 DAS recorded the highest ginger breadth at all the considered time intervals of 100, 130 and 160 DAP which was statically *at par* with the treatment of Cowpea in alternate rows of Ginger; incorporated 40 DAS (Table 1). Better initial weed suppression with higher intercrop density, vacation of inter row spaces at 40 DAP and availability of extra nitrogen fixed by legume cowpea to the ginger might have proved beneficial under cowpea and ginger intercropping in additive planting geometry.

Weed management with Metribuzin 500 g ha⁻¹ pre-em + HW 70, 100 and 140 DAP recorded significantly higher rhizome length of 14.1 cm, 20.4 cm and 22.7 cm in the year 2014-15 and 14.8 cm, 21.6 cm and 23.5 cm in 2015-16 at 100, 130 and 160 DAP, respectively. In both the years (2014-15 and 2015-16), pre-emergence application of Metribuzin 500 g ha⁻¹ pre-em + HW 70, 100 and 140 DAP was significantly superior to all the treatments in respect of rhizome breadth other than Oxadiargyl 90 g ha⁻¹ pre-em + HW 70, 100 and 140 DAP where both the treatments were *at par* (Table 1). A prolong weed free environment under the Metribuzin treatment might have brought better vegetative growth of

ginger causing better yield attributes. This result is in concomitance with the findings of Yadav and Sharma [4] in pearl millet, Pandey and Verma [5] in wheat treated with Metribuzin.

3.2 Ginger Fingers per Clump

Intercropping of Cowpea in between Ginger; incorporated 40 DAS recorded the highest ginger fingers per clump at all the considered time intervals of 100, 130 and 160 DAP and it was statically *at par* with the treatment Cowpea in alternate rows of Ginger; incorporated 40 DAS in both the years (Table 2). With a higher number of cowpea plants per unit area, there was better weed suppression preventing weed competition at the critical growth stages of ginger, leading to better spread of ginger rhizome. Similar result was reported by Jalilian et al. [6] in inter cropping system of Bitter vetch and Safflower where a closer row ratio of 2:2 recorded better results in comparison to 3:2, 4:2 and 5:2 row ratios.

Application of Metribuzin 500 g ha⁻¹ pre-em + HW 70, 100 and 140 DAP recorded significantly highest ginger finger clump of 8.5, 11.7 and 15.3, respectively in 2014-15 and 9.4, 14.5 and 17.0, respectively 2015-16 at all the considered time intervals of 100, 130 and 160 DAP as compared to other weed management practices (Table 2). Herbicidal activity resulted in excellent weed control for a longer period allowing the crop to grow in almost weed free condition causing enhanced growth of ginger rhizome. Tewari et al.[7] and Abdullah et al. [8] reported similar findings in potato.

3.3 Dry Matter Content (%) of Ginger

The highest ginger dry matter content of 33.5%, 53.2% and 64.6% in 2014-15 and 35.9%, 54.5% and 66.4% in 2015-16 at all the considered time intervals of 100, 130 and 160 DAP, respectively was recorded in the inter cropping system Cowpea in between Ginger; incorporated 40 DAS, which was statistically *at par* with the treatment Cowpea in alternate rows of Ginger; incorporated 40 DAS (Table 3). Higher density of cowpea resulted in better weed suppression at the initial growth stages of ginger. Also, cowpea being a leguminous crop, some extra Nitrogen was perhaps made available to ginger by the companion legume which could cause better vegetative growth of ginger and increased

photosynthate production, resulted in increased crop growth rate and ultimately increased the dry matter content. This might be attributed to higher rate of metabolic functions contributing for increased growth by virtue of better nutrient availability and uptake by an individual plant Singh et al., [9].

At 100, 130 and 160 DAP, weed management treatment Metribuzin 500 g ha⁻¹ pre-em + HW 70, 100 and 140 DAP recorded significantly highest dry matter content of 35.6%, 58.0% and 70.6%, respectively in 2014-15 and 37.4%, 59.8% and 72.4%, respectively in 2015-16 (Table 3). A higher rate of photosynthates accumulation under a prolonged weed free environment increased the crop growth leading to higher dry matter content under this weed management treatment. Similar, results were reported by Lawogtoma et al. [10] on Amaranthus.

3.4 Rhizome Yield (kg ha⁻¹) of Ginger

In both the years 2014-15 and 2015-16, highest ginger yield of 7542 kg ha⁻¹ and 8633 kg ha⁻¹, respectively was recorded in the legume intercropping system of Cowpea in between Ginger; incorporated 40 DAP but it was statistically *at par* with the treatment Cowpea in alternate rows of Ginger; incorporated 40 DAP. However, both the treatments produced significantly higher fresh rhizome yield over other treatments (Table 4). Restricting the weeds below economic threshold level due to weed smothering ability of higher density of cowpea and nitrogen supplementation contributed towards higher dry matter content and better growth of ginger under these two treatments could have finally resulted higher rhizome yield in these treatments. Tewari et al. [7] reported similar findings from a study on potato.

Rhizome yield of 7817 kg ha⁻¹ and 9340 kg ha⁻¹ in 2014-15 and 2015-16, respectively was recorded in the pre-emergence application of Metribuzin 500 g ha⁻¹ pre-em + HW 70, 100 and 140 DAP which was significantly higher than yield from other treatments (Table 4). This weed management practice caused significantly better growth of ginger as observed from growth and yield attributing parameters. Singh, 2000 recorded similar results due to Metribuzin treatment in potato.

Table 1. Length (cm) and breadth (cm) of ginger rhizome at different days after planting

Treatments	100 DAP				130 DAP				160 DAP			
	2014-15		2015-16		2014-15		2015-16		2014-15		2015-16	
	Length	Breadth	Length	Breadth	Length	Breadth	Length	Breadth	Length	Breadth	Length	Breadth
Cropping system												
I ₁ : G+C (2:1); C incorp. 40 DAS	11.1	6.1	11.2	6.4	14.1	8.4	14.4	8.1	15.8	10.7	16.1	10.1
I ₂ : G+C (3:1); C incorp. 40 DAS	11.5	6.2	11.6	6.5	14.5	8.7	15.0	8.6	16.5	11.0	16.7	10.7
I ₃ : C in between G; incorp. 40 DAS	13.7	7.5	14.4	7.7	18.9	10.6	19.7	10.6	21.0	13.0	21.6	12.6
I ₄ : C in alternate rows; incorp. 40 DAS	13.2	7.2	13.7	7.5	18.3	10.2	19.2	10.0	20.3	12.6	21.1	12.1
CD _{P=0.05}	1.0	0.6	1.2	0.8	1.1	0.7	1.2	0.9	1.1	1.1	1.2	1.1
SEm±	0.3	0.2	0.4	0.3	0.4	0.2	0.4	0.3	0.4	0.7	0.4	0.4
Weed management												
W ₁ : Weedy	10.4	5.7	10.5	5.9	10.5	7.2	10.9	6.4	12.0	7.5	12.3	7.9
W ₂ : HW 40, 70, 100 and 140 DAP	12.2	6.6	12.3	6.9	16.4	9.4	16.9	9.3	18.6	12.1	18.9	11.3
W ₃ : Oxadiargyl 90 g ha ⁻¹ pre-em+ HW 70, 100 and 140 DAP	12.7	7.1	13.3	7.3	18.4	10.2	18.8	10.3	20.2	13.0	20.8	12.3
W ₄ : Metribuzin 500 g ha ⁻¹ pre-em+ HW 70, 100 and 140 DAP	14.1	7.6	14.8	7.9	20.4	11.1	21.6	11.4	22.7	14.3	23.5	13.5
CD _{P=0.05}	1.0	0.6	1.2	0.8	1.1	0.7	1.2	0.9	1.1	1.1	1.2	1.1
CV (%)	9.7	11.0	11.5	14.1	7.7	9.1	8.2	11.3	7.3	11.3	7.6	11.4
SEm±	0.3	0.2	0.4	0.3	0.4	0.2	0.4	0.3	0.4	0.7	0.4	0.4

DAS- Days after sowing; DAP- Days after planting; G- Ginger, C- Cowpea; HW- Hand weeding, incorp- Incorporated

Table 2. Ginger fingers per clump (No.s clump⁻¹) at different days after planting

Treatments	100 DAP		130 DAP		160 DAP	
	2014-15	2015-16	2014-15	2015-16	2014-15	2015-16
Cropping system						
I ₁ : G+C (2:1); C incorp. 40 DAS	6.8	7.3	8.8	11.3	10.8	13.3
I ₂ : G+C (3:1); C incorp. 40 DAS	6.6	7.4	8.9	11.2	10.9	12.8
I ₃ : C in between G; incorp. 40 DAS	7.5	8.3	10.7	12.7	13.3	14.8
I ₄ : C in alternate rows; incorp. 40 DAS	7.4	8.3	10.8	12.5	13.0	14.6
CD _{P=0.05}	0.5	0.8	0.6	0.9	1.0	0.9
SEm±	0.2	0.3	0.2	0.3	0.4	0.3
Weed management						
W ₁ : Weedy	5.9	5.9	6.3	6.8	6.5	7.8
W ₂ : HW 40, 70, 100 and 140 DAP	7.1	7.8	10.4	13.1	13.1	14.9
W ₃ : Oxadiargyl 90 g ha ⁻¹ pre-em+ HW 70, 100 and 140 DAP	7.6	8.4	10.8	13.3	14.1	15.9
W ₄ : Metribuzin 500 g ha ⁻¹ pre-em+ HW 70, 100 and 140 DAP	8.5	9.4	11.7	14.5	15.3	17.0
CD _{P=0.05}	0.5	0.8	0.6	0.9	1.0	0.9
CV (%)	8.7	12.5	7.9	9.2	10.2	7.8
SEm±	0.2	0.3	0.2	0.3	0.4	0.3

DAS- Days after sowing; DAP- Days after planting; G- Ginger, C- Cowpea; HW- Hand weeding, incorp- Incorporated

Table 3. Dry matter content (%) of ginger at different days after planting

Treatments	130 DAP		160 DAP		190 DAP	
	2014 -15	2015 -16	2014 -15	2015 -16	2014 -15	2015 -16
Cropping system						
I ₁ : G+C (2:1); C incorp. 40 DAS	26.0	27.2	47.1	48.9	58.4	60.5
I ₂ : G+C (3:1); C incorp. 40 DAS	26.6	29.0	48.1	49.8	60.1	62.4
I ₃ : C in between G; incorp. 40 DAS	33.5	35.9	53.2	54.5	64.6	66.4
I ₄ : C in alternate rows; incorp. 40 DAS	32.9	35.0	52.2	53.7	63.8	65.5
CD _{P=0.05}	2.3	2.5	1.5	2.5	2.5	2.7
SEm±	0.8	0.9	0.5	0.9	0.9	0.9
Weed management						
W ₁ : Weedy	20.8	22.8	33.3	35.6	42.4	45.5
W ₂ : HW 40, 70, 100 and 140 DAP	30.6	32.2	53.1	55.5	65.7	67.5
W ₃ : Oxadiargyl 90 g ha ⁻¹ pre-em+ HW 70, 100 and 140 DAP	32.1	34.7	55.1	56.0	68.0	69.6
W ₄ : Metribuzin 500 g ha ⁻¹ pre-em+ HW 70, 100 and 140 DAP	35.6	37.4	58.0	59.8	70.6	72.4
CD _{P=0.05}	2.3	2.5	2.6	2.5	2.2	2.5
CV (%)	9.3	9.4	6.3	5.9	5.0	5.1
SEm±	0.8	0.9	0.9	0.9	0.9	0.9

DAS- Days after sowing; DAP- Days after planting; G- Ginger, C- Cowpea; HW- Hand weeding, incorp- Incorporated

Table 4. Fresh rhizome yield (kg ha⁻¹) of ginger

Treatments	2014-15	2015-16
Cropping system		
I ₁ : G+C (2:1); C incorp. 40 DAS	5846	6175
I ₂ : G+C (3:1); C incorp. 40 DAS	5925	6454
I ₃ : C in between G; incorp. 40 DAS	7542	8633
I ₄ : C in alternate rows; incorp. 40 DAS	7338	8505
CD _{P=0.05}	419	635
SEm±	145	220
Weed management		
W ₁ : Weedy	5021	4825
W ₂ : HW 40, 70, 100 and 140 DAP	6533	7396
W ₃ : Oxadiargyl 90 g ha ⁻¹ pre-em+ HW 70, 100 and 140 DAP	7279	8208
W ₄ : Metribuzin 500 g ha ⁻¹ pre-em+ HW 70, 100 and 140 DAP	7817	9340
CD _{P=0.05}	338	635
CV (%)	8	10
SEm±	145	220

DAS- Days after sowing; DAP- Days after planting; G- Ginger, C- Cowpea; HW- Hand weeding, incorp- Incorporated

4. CONCLUSION

The current study revealed that sowing of Cowpea in between the rows of Ginger and incorporated at 40 days after sowing and Cowpea in between alternate rows of Ginger and incorporated at 40 days after sowing, recorded equally better results in terms of yield and yield attributing parameters. Whereas, weed management with Metribuzin 500 g ai ha⁻¹ + hand weeding

(HW) at 70, 100 and 140 days after planting (DAP) provided significantly superior results of length and breadth of ginger rhizome, fingers per clump, dry matter content and rhizome yield.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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