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Effect of legume intercropping system and weed management practices on ginger (*Zingiber officinale*) rhizome and oil yield in acidic soil condition

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Abstract
A field study was conducted for two seasons in 2014-15 and 2015-16 in the ICR Farm of Assam Agricultural University, Jorhat-13, Assam, India with the objective to understand the effect of legume intercropping system in combination with different weed management practices on ginger rhizome and oil yield in acidic soil condition. There were total 16 numbers of treatment combinations, which comprised of four legume intercropping systems and four weed management practices. Amongst the legume intercropping system, Cowpea sown in between the rows of Ginger and incorporated into the soil at 40 days after sowing (DAS), recorded superior results in terms of stem girth of ginger plant, tillers per clump, leaves per tillers and rhizome parameters. Whereas, chemical weed management with Metribuzin 500 g ai ha^{-1} plus hand weeding at 70, 100 and 140 days after planting (DAP) recorded better yield attributing parameters, contributing towards highest ginger rhizome and oil yield.

Keywords: Cowpea, additive series, metribuzin, pre-emergence herbicide, crop weed competition

Introduction
Ginger is an important cash crop, contributing towards agricultural economy. It is either available in its raw form or is processed into different value-added forms like candy, flakes, oil etc. Due to its antiseptic and curative properties, ginger is also used to cure various ailments Adamade *et al.* (2017) [1].

In ginger cultivation, earthing up is the most important inter-cultural operation. But to carry out the earthing up process in ease, rhizomes must be planted maintaining sufficient space between ginger rows. Also, being a long duration crop, it takes relatively more time for its establishment and thus first earthing up can be done approximately after 2 months of planting. This provides ample of time for weeds to invade the vacant spaces leading to crop weed competition at the critical growth stage of ginger.

Growers can outrun the challenge of weed invasion in ginger fields by combining suitable weed management practices with legume intercropping. Weed control before its emergence will allow the crop to grow without any completion for the available resources. And legume crops, besides enhancing the soil condition will also fetch a scope of additional income to the growers. Thus, the field study was initiated to understands the effect fast growing legume as an intercrop with suitable weed management practices on ginger rhizome and oil yield in acidic soils of Assam.

Materials and Methods
The current study was conducted in the ICR Farm of Assam Agricultural University, Jorhat-13, Assam, India during 2014-15 and 2015-16. A total of 16 treatment combinations were considered with 3 replications, totaling to 48 numbers of sub-plots. Each sub-plot comprised an area of 20 m^2, accounting for a net area of 960 m^2 and gross area 1482 m^2. Organic manure @ 10 t ha^{-1} was applied and incorporated into the soil during the time of final bed preparation. Recommended dose of urea (46% N), single super phosphate (16% P_2O_5) and muriate of potash (60% K_2O) was applied in splits.

The treatments comprised of 4 legume intercropping system and 4 weed management Practices, totaling to 16 treatment combinations. Legume intercropping comprised of Ginger + Cowpea in 2:1 ratio and Cowpea incorporated at 40 DAS (I_1), Ginger + Cowpea in 3:1 ratio and Cowpea incorporated at 40 DAS (I_2), Cowpea in between rows of Ginger and incorporated at 40 DAS (I_3) and Cowpea in between alternate rows of Ginger and incorporated at 40 DAS (I_4).

Whereas, the weed management practices comprised of Weedy check (W_1), Hand weeding at 40, 70, 100 and 140 DAP (W_2), Pre-emergence application of Oxadiargyl 90 g ai ha^{-1} + hand weeding at 70, 100 and 140 DAP (W_3) and Pre-emergence application of Metribuzin 500 g ai ha^{-1} + hand weeding at 70, 100 and 140 DAP (W_4).

Before planting, ginger rhizomes (variety Nadia) were pre-treated with Mancozeb solution @ 3.0 g kg^{-1} rhizome and shade dried overnight. Rhizomes were planted maintaining a spacing of 60 cm row to row and 25 cm between rhizome to rhizome. A short duration fodder variety of cowpea (UPC-278), was sown as an intercrop as per the treatment requirement on the same day of ginger planting. Cowpea was uprooted and incorporated in the soil at 40th day after sowing.

Herbicides were applied on the 3rd day after planting of ginger crop, with a spray volume of 500 L ha^{-1}. Earthing up operation was done after crop establishment, first at 60 DAP and later at 100 DAP in all treated plots, except for Weedy plots, with no earthing-up operations. Protection measures against ginger soft rot were adopted as per package of practices recommended by Assam Agricultural University where Mancozeb with alternate cycles of Streptomycin was applied throughout the monsoon season.

At harvest, ginger rhizomes were digged out with the help of spade. Soil particles attached to it were removed and fresh weight was recorded for each plot and was converted to kg ha^{-1}. For estimation of oil, fresh rhizomes from each treatment were dried, crushed and placed in a thimble and extracted with light petroleum ether for six hours in a Soxhlet extraction unit as per method described by AOAC (1980). The per cent oil content in ginger was estimated as:

$$\text{Per cent oil content} = \frac{W_2 - W_1}{X} \times 100$$

Where

W_1 = Weight of the empty container (g)

W_2 = Weight of empty container + weight of oil (g)

X = Weight of sample taken for extraction (g)

From the oil content, oil yield was calculated out as follows:

Oil yield= Oil content x Yield (kg ha^{-1})

Result and Discussion

Stem girth (cm) of ginger

Available data indicated that stem girth recorded at 100, 130 and 160 DAP was highest with 2.93, 3.37 and 3.69 cm in 2014-15 and 3.13, 3.60 and 3.80 cm in 2015-16, respectively in the legume intercropping system of Cowpea in between rows of Ginger and incorporated at 40 DAS and was statistically *at par* with the treatment Cowpea in alternate rows of ginger and incorporated at 40 DAS (Table 1). Planting of cowpea in additive series caused better initial weed suppression, thereby preventing critical period of crop weed competition and allowing better vegetative growth of ginger.

Significantly higher stem girth of 3.13, 3.52 and 3.92 cm in 2014-15 and 3.23, 3.74 and 4.08 cm in 2015-16 at 100, 130 and 160 DAP, respectively was recorded in the treatment Metribuzine 500 g ha^{-1} pre-em + HW 70, 100 and 140 DAP. Application of Metribuzin controlled weeds for a longer period, allowing the plant to grow in a weed free condition and helped to escape the critical period of growth without competition. All these factors might have contributed to bigger girth of mother rhizome.

Ginger tillers per clump (No.s clump^{-1})

Legume intercropping system with Cowpea in between rows of Ginger and incorporated at 40 DAS and Cowpea in alternate rows of ginger and incorporated at 40 DAS recorded similar results in terms of ginger tillers per clump at all the considered time intervals of 100, 130 and 160 DAP in 2014-15 and 2015-16 (Table 2). Higher density of cowpea in these treatments caused better initial weed suppression. Also, cowpea being a leguminous crop might have provided additional nitrogen to the soil, thus supplying the crop with adequate nutrition. Similar finding of yield attributing parameters of ginger was reported by Nwaogu *et al.* (2013) [2].

At all the considered time intervals of 100, 130 and 160 DAP, pre-emergence application of Metribuzin 500 g ha^{-1} pre-em + HW 70, 100 and 140 DAP recorded highest ginger tillers per clump of 8.9, 10.6 and 11.9, respectively in 2014-15 and of 9.3, 11.4 and 13.5, respectively in 2015-16 (Table 2). Control of weeds before its emergence with Metribuzin allowed the plant to grow without any competition for available resources, thus contributing to higher numbers of tiller per clump. This result is in concomitance with the findings of Pandey and Verma (2002) [3], who reported higher tillers of wheat in Metribuzin treated plots.

Ginger leaves per tiller (No.s tiller^{-1})

The highest leaves per tiller of 13.8, 48.7 and 51.6 in 2014-15 and 17.3, 51.5 and 60.8 in 2015-16 at 100, 130 and 160 DAP, respectively was recorded in legume intercropping system of Cowpea in between rows of Ginger and incorporated at 40 DAS which was statistically *at par* with the treatment Cowpea in alternate rows of ginger and incorporated at 40 DAS (Table 3). Better weed control and soil enrichment by cowpea might have contributed towards better yield attributing Paraments of ginger. Similar result in legume intercropping in ginger crop was reported by Nwaogu and Muogbo (2015) [4].

There was significantly higher leaves per tiller of 16.3, 59.3 and 68.9 in 2014-15 and 20.5, 63.8 and 72.3 in 2015-16 in the treatment with pre-emergence application of Metribuzin 500 g ha^{-1} pre-em + HW 70, 100 and 140 DAP at all the stages *viz.*, 100, 130 and 160 DAP, respectively (Table 3). Very effective weed control and a longer weed free situation under Metribuzin treatment might have contributed to higher number of leaves per tiller of ginger. Similar findings on wheat with Metribuzin were also reported by Singh and Turkhede (1991) [5].

Length (cm) of ginger rhizome

At 100, 130 and 160 DAP, highest rhizome length of 13.7, 18.9 and 21.0 cm, respectively in 2014-15 and 14.4, 19.7 and 21.6 cm respectively, in 2015-16 was recorded in the treatment Cowpea in between rows of Ginger and incorporated at 40 DAS, which was statically *at par* with the treatment Cowpea in alternate rows of ginger and incorporated at 40 DAS (Table 4). Better initial weed suppression with higher intercrop density, vacation of inter row spaces at 40 DAP and availability of extra nitrogen fixed by legume intercrop could have caused higher values under cowpea and ginger intercropping in additive series planting geometry. Tewari *et al.* (1988) [6] reported similar findings from a study on potato.

Pre-emergence application of Metribuzin 500 g ha^{-1} pre-em +

HW 70, 100 and 140 DAP recorded significantly higher rhizome length of 14.1, 20.4 and 22.7 cm in the year 2014-15 and 14.8, 21.6 and 23.5 cm in 2015-16 at 100, 130 and 160 DAP, respectively (Table 4). Prolonged weed free environment resulting better vegetative growth under the treatments might have attributed towards better rhizome growth. This result is in accordance with the findings of Yadav and Sharma (1995) [7] in pearl millet.

Rhizome yield (kg ha^{-1}) of ginger

In both the years 2014-15 and 2015-16, highest ginger yield of 7542 and 8633 kg ha^{-1}, respectively was recorded in the legume intercropping system of Cowpea in between rows of Ginger and incorporated at 40 DAP but it was statistically *at par* with the treatment Cowpea in alternate rows of ginger and incorporated at 40 DAP (Table 5). Better vegetative growth contributing to higher photosynthates accumulation under these two treatments finally could have resulted higher rhizome yield in these treatments. Tewari *et al.* (1988) [6] reported similar findings from a study on potato.

Among the weed management practices, significantly higher ginger yield of 7817 and 9340 kg ha^{-1} in 2014-15 and 2015-16, respectively was recorded in pre-emergence application of Metribuzin 500 g ha^{-1} pre-em + HW 70, 100 and 140 DAP (Table 5). Pre-emergence application of Metribuzin 500 g ha^{-1} followed by hand weeding caused significantly better growth of ginger as observed from the vegetative parameters causing higher fresh rhizome yield of ginger. Similar findings on Metribuzin application in potato crop was also reported by Singh (2000) [8], and in turmeric by Rana *et al*. (2017) [9].

Ginger oil (kg ha^{-1}) estimation

The highest ginger oil yield of 203.6 and 233.1 kg ha^{-1} in 2014-15 and 2015-16, respectively was recorded in the treatment Cowpea in between rows of Ginger and incorporated at 40 DAS which was statistically *at par* with the treatment Cowpea in alternate rows of ginger and incorporated 40 DAS (Table 5). Higher rhizome yield in these treatments due to better photosynthate accumulation might have resulted higher oil yield.

Controlling weeds with pre-emergence application of Metribuzin 500 g ha^{-1} pre-em + HW 70, 100 and 140 DAP, recorded statistically higher ginger oil yield of 211.1 and 252.1 kg ha^{-1} in 2014-15 and 215-16, respectively (Table 5). A higher rhizome yield reflected on higher ginger oil yield. This result is in conformity with the reports of Shinde *et al*. (1990) [10] in groundnut, Chand *et al*. (2007) [11] on Geranium and Singh *et al*. (2009) [12] on coriander.

Table 1: Plant height (cm) of ginger 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	2.61	2.77	3.13	3.34	3.49	3.49
I_2: G+C (3:1); C incorp. 40 DAS	2.58	2.80	3.13	3.36	3.48	3.53
I_3: C in between G; incorp. 40 DAS	2.93	3.13	3.37	3.60	3.69	3.80
I_4: C in alternate rows; incorp. 40 DAS	2.88	3.04	3.35	3.56	3.60	3.76
$CD_{P=0.05}$	0.13	0.20	0.21	0.16	0.19	0.22
Weed management						
W_1: Weedy	2.21	2.39	2.68	2.76	2.85	2.81
W_2: HW 40, 70, 100 and 140 DAP	2.74	3.03	3.32	3.61	3.74	3.71
W_3: Oxadiargyl 90 g ha^{-1} pre-em+ HW 70, 100 and 140 DAP	2.93	3.01	3.30	3.60	3.72	3.77
W_4: Metribuzine 500 g ha^{-1} pre-em+ HW 70, 100 and 140 DAP	3.13	3.23	3.52	3.74	3.92	4.08
$CD_{P=0.05}$	0.13	0.20	0.21	0.16	0.19	0.22
CV (%)	5.54	8.23	7.77	5.49	6.26	7.27

DAS- Days after sowing; DAP- Days after planting; HW- Hand weeding, in corp-Incorporated

Table 2: Ginger tillers per clump (Nos 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	6.7	6.4	7.6	7.8	8.7	9.9
I_2: G+C (3:1); C incorp. 40 DAS	6.5	6.6	7.0	7.8	8.3	9.3
I_3: C in between G; incorp. 40 DAS	8.1	8.2	9.8	10.1	10.7	11.3
I_4: C in alternate rows; incorp. 40 DAS	8.3	8.1	9.8	9.9	10.4	11.0
$CD_{P=0.05}$	0.9	0.9	0.9	0.7	1.0	1.0
Weed management						
W_1: Weedy	5.3	3.9	5.7	4.8	5.9	5.4
W_2: HW 40, 70, 100 and 140 DAP	7.3	8.2	8.6	9.4	9.7	11.0
W_3: Oxadiargyl 90 g ha^{-1} pre-em+ HW 70, 100 and 140 DAP	8.1	7.9	9.3	10.1	10.6	12.2
W_4: Metribuzine 500 g ha^{-1} pre-em+ HW 70, 100 and 140 DAP	8.9	9.3	10.6	11.4	11.9	13.5
$CD_{P=0.05}$	0.6	0.9	0.9	0.7	1.0	1.0
CV (%)	14.7	15.1	12.4	10.0	12.3	11.5

DAS- Days after sowing; DAP- Days after planting; HW- Hand weeding, incorp- Incorporated

Table 3: Ginger leaves per tiller (Nos tiller^{-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	10.3	12.9	35.8	39.2	39.0	46.4
I_2: G+C (3:1); C incorp. 40 DAS	9.8	12.9	34.6	37.7	30.5	44.6
I_3: C in between G; incorp. 40 DAS	13.8	17.3	48.7	51.5	51.6	60.8
I_4: C in alternate rows; incorp. 40 DAS	13.3	16.3	46.6	49.4	49.4	57.6
$CD_{P=0.05}$	1.0	1.6	2.9	2.4	2.4	3.0
Weed management						
W_1: Weedy	3.6	4.3	7.5	9.2	12.6	14.2
W_2: HW 40, 70, 100 and 140 DAP	12.8	16.2	46.6	49.7	55.5	57.5
W_3: Oxadiargyl 90 g ha^{-1} pre-em+ HW 70, 100 and 140 DAP	14.7	18.5	52.2	55.1	61.9	65.4
W_4: Metribuzine 500 g ha^{-1} pre-em+ HW 70, 100 and 140 DAP	16.3	20.5	59.3	63.8	68.9	72.3
$CD_{P=0.05}$	1.0	1.6	2.9	2.4	2.4	3.1
CV (%)	10.3	12.7	8.4	6.6	6.6	7.1

DAS- Days after sowing; DAP- Days after planting; HW- Hand weeding, incorp- Incorporated

Table 4: Length (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
Cropping system						
I_1: G+C (2:1); C incorp. 40 DAS	11.1	11.2	14.1	14.4	15.8	16.1
I_2: G+C (3:1); C incorp. 40 DAS	11.5	11.6	14.5	15.0	16.5	16.7
I_3: C in between G; incorp. 40 DAS	13.7	14.4	18.9	19.7	21.0	21.6
I_4: C in alternate rows; incorp. 40 DAS	13.2	13.7	18.3	19.2	20.3	21.1
$CD_{P=0.05}$	1.0	1.2	1.1	1.2	1.1	1.2
Weed management						
W_1: Weedy	10.4	10.5	10.5	10.9	12.0	12.3
W_2: HW 40, 70, 100 and 140 DAP	12.2	12.3	16.4	16.9	18.6	18.9
W_3: Oxadiargyl 90 g ha^{-1} pre-em+ HW 70, 100 and 140 DAP	12.7	13.3	18.4	18.8	20.2	20.8
W_4: Metribuzine 500 g ha^{-1} pre-em+ HW 70, 100 and 140 DAP	14.1	14.8	20.4	21.6	22.7	23.5
$CD_{P=0.05}$	1.0	1.2	1.1	1.2	1.1	1.2
CV (%)	9.7	11.5	7.7	8.2	7.3	7.6

DAS- Days after sowing; DAP- Days after planting; HW- Hand weeding, incorp- Incorporated

Table 5: Fresh rhizome yield (kg ha^{-1}) of ginger

Treatments	Rhizome yield (kg ha^{-1})		Oil yield (kg ha^{-1})	
	2014-15	2015-16	2014-15	2015-16
Cropping system				
I_1: G+C (2:1); C incorp. 40 DAS	5846	6175	157.8	166.7
I_2: G+C (3:1); C incorp. 40 DAS	5925	6454	160.0	174.3
I_3: C in between G; incorp. 40 DAS	7542	8633	203.6	233.1
I_4: C in alternate rows; incorp. 40 DAS	7338	8505	198.1	229.6
$CD_{P=0.05}$	419	635	11.3	17.1
Weed management				
W_1: Weedy	5021	4825	135.6	130.3
W_2: HW 40, 70, 100 and 140 DAP	6533	7396	176.4	199.7
W_3: Oxadiargyl 90 g ha^{-1} pre-em+ HW 70, 100 and 140 DAP	7279	8208	196.5	221.6
W_4: Metribuzine 500 g ha^{-1} pre-em+ HW 70, 100 and 140 DAP	7817	9340	211.1	252.1
$CD_{P=0.05}$	338	635	9.1	17.1
CV (%)	8	10	6.0	6.1

DAS- Days after sowing; DAP- Days after planting; HW- Hand weeding, incorp- Incorporated

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