

Original Research Article

Assessing Crop Growth Indices of *Nadia* variety of Ginger (*Zingiber officinale* Rosc.) Under Legume Intercropping and Weed Management Practices

ABSTRACT

A field experiment was conducted during 2014-15 and 2015-16 in the Instruction-cum-Research Farm of Assam Agricultural University, Jorhat-13, Assam, India. The objective of this experiment is to understand the impact of legume intercropping system in combination with different weed management practices on the growth indices of ginger crop. *Nadia* variety, a commercially grown variety of ginger in Assam. A total of 16 treatment combinations were considered which comprised of 4 inter-cropping systems along with 4 weed management practices. Amongst the legume inter-cropping, Cowpea in between rows of Ginger; incorporated at 40 days after sowing (DAS) and Cowpea in alternate rows of Ginger; incorporated at 40 DAS, recorded the better results in terms of Leaf area index (LAI), Crop growth rate (CGR), Absolute growth rate (AGR) and yield of *Nadia* variety ginger. Whereas amongst the weed management practices, pre-emergence application of Metribuzin 500 gm. ai ha⁻¹ + hand weeding (HW) at 70, 100 and 140 days after planting (DAP) scored higher in growth indices and ginger yield, but neither the legume intercropping systems nor the weed management treatments had any significant impact on harvest index.

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

INTRODUCTION

Ginger is one of the high valued commercial cash-oriented crops. India is one of the major producers and consumers of ginger, accounting for about 30-40% of the global share of production, followed by China, Nepal and Indonesia (Gracy *et al.*, 2013). As per the matrix available in *Statista* (<https://www.statista.com/statistics/870956/ginger-production-by-state-india/>) in India, Assam was the leading state in ginger production in fiscal year 2018. This stood at nearly 168 thousand metric tons, contributing about 17.5% to the country's ginger production.

One important commercially grown ginger variety in Assam is *Nadia* variety. This variety is majorly cultivated for its high yield fetching ability, with high dry recovery of 22% and low crude fiber of 3.9%, but crops and their varieties have its own unique ways of responding and interacting with the environmental

factors, contributing towards yield and yield attributing parameters. Thus, the current study was **planted** with the intent to understand the impact of intercropping system in combination with different weed management practices, on various growth indices of Nadia variety of ginger crop.

MATERIALS AND METHODS

Field preparation

The current study was conducted for two seasons (2014-15 and 2015-16) in the ICR Farm of Assam Agricultural University, Jorhat, Assam, India, having an elevation of 86.56 meters above mean sea level. The experimental plots were prepared adequately and demarcated into 20 m² subplots, comprising of 3 replications and 16 treatment combinations totaling to 48 numbers of sub-plots, accounting for 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 **marinate** of potash (60% K₂O) were applied.

Treatment details

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 **gm. ai ha⁻¹** + hand weeding at 70, 100 and 140 DAP and W₄: Pre-emergence application of Metribuzin 500 **gm. ai ha⁻¹** + hand weeding at 70, 100 and 140 DAP.

Planting materials

Good quality rhizomes of *Nadia* variety of ginger were pre-treated with Mancozeb @ 3.0 **gm. Kg⁻¹** rhizome and planted in a spacing of 60 cm between two rows and 25 cm between rhizomes. UPC-278, a fodder variety of cowpea was sown as an inter-crop as per the treatment requirement and was uprooted and incorporated in the soil at 40th day after sowing. Ginger planting and Cowpea sowing was completed on the same.

Herbicide application and inter-cultural operations

Pre-emergence herbicides were applied with a spray volume of 500 L ha⁻¹ on the 3rd day. The plots were mulched with rice straw @ 4 t ha⁻¹ in two splits, immediately after herbicide application and second at 70 DAP. Light earthing up was done at 60 and 100 DAP for ginger in all treated plots. Weedy plots were left as such, with no earthing up operations. Mancozeb application started with alternate cycles of Streptomycin before onset of monsoon and continued during the monsoon season to prevent fungal and bacterial infection.

Harvesting

In both years, ginger crop was harvested **after 262 days from** 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.

Estimations

- a. **Leaf area index (LAI) of ginger at different days after planting:** Leaf area was recorded using the leaf area meter and then LAI was calculated out using the following formula as per Yoshida (1983)

$$\text{LAI} = \frac{\text{Total leaf area of the plant}}{\text{Total ground area covered by the plant}}$$

- b. **Crop growth rate ($\text{g m}^{-2} \text{day}^{-1}$) of ginger at different days after planting:** It was calculated using the formula of Watson (1952) and expressed as $\text{gm. m}^{-2} \text{day}^{-1}$.

$$\text{CGR} = \frac{W_2 - W_1}{(t_2 - t_1)S} \quad (\text{gm. m}^{-2} \text{day}^{-1})$$

Where, W_1 = Dry weight of the crop at first harvest (gm.), W_2 = Dry weight of the crop at second harvest (gm.), t_1 = Time at first harvest (days), t_2 = Time at second harvest (days) and S = Area from which dry weight was recorded (m^2)

- c. **Absolute growth rate ($\text{g plant}^{-1} \text{day}^{-1}$) of ginger at different days after planting:** It was calculated using the formula of Watson (1952) and expressed as $\text{gm. m}^{-2} \text{day}^{-1}$.

$$\text{AGR} = \frac{W_2 - W_1}{(t_2 - t_1)} \quad (\text{gm. m}^{-2} \text{day}^{-1})$$

Where, W_1 = Dry weight of the crop at first harvest (gm.), W_2 = Dry weight of the crop at second harvest (gm.), t_1 = Time at first harvest (days) and t_2 = Time at second harvest (days)

- d. **Harvest index of ginger:** Harvest index was calculated for ginger at the time of harvest by using the following formula (Yosida, 1983).

$$\text{HI} = \frac{\text{Economic yield (kg ha}^{-1}\text{)}}{\text{Biological yield (kg ha}^{-1}\text{)}}$$

RESULT AND DISCUSSION

Leaf area index (LAI) of ginger at different days after planting

Significantly higher LAI of 4.27, 18.25 and 25.17 in 2014-15 and 5.49, 20.11 and 28.02 in 2015-16 at 100, 130 and 160 DAP, respectively was recorded in the treatment Cowpea in between Ginger; incorporated at 40 DAS (Table 1). It was closely followed by the treatment Cowpea in alternate rows of Ginger;

incorporated at 40 DAS. Higher cowpea population in the mentioned treatment might have helped better suppression of weeds in the critical crop growth stage, contributing to a greater number of leaves resulting in higher LAI in the mentioned treatment.

Weed management treatment Metribuzine 500 gm. ha⁻¹ pre-em + HW 70, 100 and 140 DAP higher LAI of 5.07, 21.80 and 29.76 in 2014-15 and 6.50, 24.63 and 33.48 in 2015-16 at 100, 130 and 160 DAP, respectively (Table 1). Very effective weed control and a longer weed free situation under Metribuzin treatment might have contributed to higher number of main shoot leaves resulting in higher LAI. Similar findings on wheat with Metribuzin were also reported by Singh and Turkhede (1991).

Crop growth rate (gm. m⁻² day⁻¹) and absolute growth rate (gm. m⁻² day⁻¹) of ginger at different days after planting

Legume intercropping system of Cowpea in between Ginger; incorporated at 40 DAS recorded the highest CGR of 32.32, 40.60 and 36.84 gm. m⁻² day⁻¹ in 2014-15 and 31.69, 41.64 and 37.70 g m⁻² day⁻¹ in 2015-16 at 130, 160 and 190 DAP, respectively. It was statistically *at par* with the treatment Cowpea in alternate rows of Ginger; incorporated at 40 DAS. A similar trend was also recorded in terms of absolute growth rate where treatment Cowpea in between Ginger; incorporated at 40 DAS recorded highest absolute growth rate and Cowpea in alternate rows of Ginger; incorporated at 40 DAS was *at par* with it (Table 2). This might be due to the fact that the increase in leaf area index resulted better interception of light which in turn increased the effective photosynthetic area leading to higher metabolic activities. Leaf is the principal organ of the photosynthate production. Total leaf area available is the integral of leaf number (Watson, 1952). Thus, increased leaf area leads to increased photosynthate production helping increase in crop growth rate and 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.*, 2010).

Pre-emergence application of Metribuzine 500 gm. ha⁻¹ pre-em + HW 70, 100 and 140 DAP resulted significantly higher CGR of 38.69, 47.86 and 44.28 gm. m⁻² day⁻¹ in 2014-15 and 37.90, 50.10 and 45.80 gm. m⁻² day⁻¹ in 2015-16 at 130, 160 and 190 DAP, respectively. Treatment with Metribuzin 500 gm. ha⁻¹ pre-em + HW 70, 100 and 140 DAP also showed superior results in content of absolute growth rate of the crop in 2014-15 and 2015-16 (Table 2). A higher rate of photosynthate accumulation under a prolonged weed free environment increased the crop growth rate and absolute growth rate under this weed management treatment. Similar, results were reported by Law-ogtoma *et al.* (2009) on Amaranthus.

Rhizome yield (Kg ha⁻¹) of ginger

Treatment of Cowpea in between Ginger; incorporated at 40 DAS recorded highest ginger yield of 7542 Kg ha⁻¹ in 2014-15 and 8633 Kg ha⁻¹ in 2015-16, which was statistically *at par* with the treatment Cowpea in alternate rows of Ginger; incorporated at 40 DAS (Table 3). Better vegetative growth and higher photosynthates accumulation as indicated by higher LAI, CGR and AGR under these two treatments

finally could have resulted higher rhizome yield in these treatments. Tewari *et al.* (1988) reported similar findings from a study on potato.

Amongst the weed management treatments, pre-emergence application of Metribuzine 500 gm. ha⁻¹ pre-em + HW 70, 100 and 140 DAP recorded significantly higher ginger yield of 7817 Kg ha⁻¹ in 2014-15 and 9340 Kg ha⁻¹ in 2015-16 (Table 3). This treatment caused significantly better growth of ginger as observed from leaf area index, crop growth rate and absolute growth rate, leading to high fresh rhizome yield of ginger. Similar findings on Metribuzine application in potato crop was reported by Singh (2000).

Harvest index of ginger

In both the years, intercropping systems had no significant effect on the harvest index of ginger. However, a highest harvest index of 0.92% in 2014-15 and 2015-16 was recorded in the treatments Cowpea in between Ginger; incorporated at 40 DAS and Cowpea in alternate rows of Ginger; incorporated at 40 DAS (Table 4). Treatments with less economic yield had lesser vegetative growth, and vice versa, leading to closer values of harvest index amongst legume inter cropping systems. Similar results in maize inter cropped with soybean was recorded by Matusso *et al.*, (2013)

Weed management treatments also did not have significant effect on the harvest index of ginger. However, a highest harvest index of 0.92% was recorded in the treatments Oxadiargyl 90 g ha⁻¹ pre-em + HW 70, 100 and 140 DAP and Metribuzine 500 g ha⁻¹ pre-em + HW 70, 100 and 140 DAP in 2014-15. But in 2015-16 a highest harvest index of 0.93% was recorded in the treatment Metribuzine 500 g ha⁻¹ pre-em + HW 70, 100 and 140 DAP (Table 4). In weedy check, crop had lanky growth with reduced yield, whereas other weed management treatments had good vegetative growth with more photosynthate accumulation contributing to higher yield. This situation might have contributed towards similar results between treatments. This is in alignment with the findings of Chandra *at al.* (2018) in wheat crop.

CONCLUSION

From the current study, it can be concluded that inter-cropping of Cowpea in additive series i.e. Cowpea in between Ginger; incorporated at 40 DAS and Cowpea in alternate rows of Ginger; incorporated at 40 DAS recorded better results in terms of different growth indices of ginger like leaf area index, crop growth rate and absolute growth rate, finally contributing towards higher yield. Also, controlling weeds before emergence with Metribuzine 500 gm. ha⁻¹ pre-em + HW 70, 100 and 140 DAP was significantly better in terms of ginger growth indices and rhizome yield.

COMPETING INTERESTS DISCLAIMER:

Authors have declared that no competing interests exist. The products used for this research are commonly and predominantly use products in our area of research and country. There is absolutely no conflict of interest between the authors and producers of the products because we do not intend to use

these products as an avenue for any litigation but for the advancement of knowledge. Also, the research was not funded by the producing company rather it was funded by personal efforts of the authors.

UNDER PEER REVIEW

Table 1. Leaf area index (LAI) of ginger at different days after planting

Treatments	2014-15			2015-15		
	100 DAP	130 DAP	160 DAP	100 DAP	130 DAP	160 DAP
Cropping system						
I ₁ : G+C (2:1); C incorp. 40 DAS	2.06	7.96	12.10	2.54	9.35	14.60
I ₂ : G+C (3:1); C incorp. 40 DAS	1.97	7.58	11.89	2.67	9.52	14.45
I ₃ : C in between G; incorp. 40 DAS	4.27	18.25	25.17	5.49	20.11	28.02
I ₄ : C in alternate rows; incorp. 40 DAS	4.03	17.30	22.69	4.99	18.37	25.37
CD _{P=0.05}	0.23	0.74	0.99	0.34	1.34	0.96
SEm±	0.08	0.12	0.26	0.46	0.34	0.33
Weed management						
W ₁ : Weedy	0.64	1.31	2.17	0.62	1.31	2.19
W ₂ : HW 40, 70, 100 and 140 DAP	2.80	12.25	17.40	3.88	14.02	20.17
W ₃ : Oxadiargyl 90 gm. ha ⁻¹ pre-em+ HW 70, 100 and 140 DAP	3.81	15.73	22.52	4.70	17.39	26.61
W ₄ : Metribuzine 500 gm. ha ⁻¹ pre-em+ HW 70, 100 and 140 DAP	5.07	21.80	29.76	6.50	24.63	33.48
CD _{P=0.05}	0.23	0.74	0.99	0.34	1.34	0.96
CV (%)	8.98	6.99	6.62	10.36	11.18	5.57
SEm±	0.08	0.12	0.26	0.46	0.34	0.33

DAS- Days after sowing; DAP- Days after planting, HW- Hand weeding, incorp.- Incorporation, pre-em- Pre-emergence

Table 2. Crop growth rate ($\text{gm. m}^{-2} \text{ day}^{-1}$) and Absolute growth rate ($\text{gm. m}^{-2} \text{ day}^{-1}$) of ginger at different days after planting

Treatments	Crop growth rate ($\text{gm. m}^{-2} \text{ day}^{-1}$)						Absolute growth rate ($\text{gm. m}^{-2} \text{ day}^{-1}$)					
	2014-15			2015-16			2014-15			2015-16		
	130 DAP	160 DAP	190 DAP	130 DAP	160 DAP	190 DAP	130 DAP	160 DAP	190 DAP	130 DAP	160 DAP	190 DAP
Cropping system												
I ₁ : G+C (2:1); C incorp. 40 DAS	21.01	29.37	25.27	21.57	30.28	26.41	3.32	4.55	4.00	3.33	4.50	4.03
I ₂ : G+C (3:1); C incorp. 40 DAS	22.40	30.35	26.73	22.50	31.73	27.23	3.46	4.67	4.15	3.54	4.77	4.02
I ₃ : C in between G; incorp. 40 DAS	32.32	40.60	36.84	31.69	41.64	37.70	4.99	6.26	5.57	4.85	6.33	5.65
I ₄ : C in alternate rows; incorp. 40 DAS	30.94	39.46	35.90	30.36	40.67	36.02	4.82	5.99	5.43	4.73	6.00	5.37
CD _{P=0.05}	2.84	3.13	3.45	2.43	3.24	3.87	0.38	0.40	0.44	0.35	0.47	0.44
SEm \pm	0.98	1.09	1.20	0.84	1.12	1.34	0.13	0.14	0.15	0.12	0.16	0.15
Weed management												
W ₁ : Weedy	5.01	8.84	5.54	5.01	8.93	5.82	0.75	1.33	0.83	0.75	1.33	0.90
W ₂ : HW 40, 70, 100 and 140 DAP	29.37	38.90	34.97	29.10	39.84	35.27	4.52	5.94	5.39	4.52	5.99	5.29
W ₃ : Oxadiargyl 90 g ha ⁻¹ pre-em+ HW 70, 100 and 140 DAP	33.60	44.18	39.94	34.11	45.46	40.47	5.38	6.92	6.27	5.23	6.82	6.05
W ₄ : Metribuzine 500 g ha ⁻¹ pre-em+ HW 70, 100 and 140 DAP	38.69	47.86	44.28	37.90	50.10	45.80	5.94	7.37	6.72	5.96	7.47	6.83
CD _{P=0.05}	2.84	3.13	3.45	2.43	3.24	3.87	0.38	0.40	0.44	0.35	0.47	0.44
CV (%)	12.76	10.76	13.28	10.98	10.78	14.58	11.08	8.96	11.13	10.35	10.48	11.10
SEm \pm	0.98	1.09	1.20	0.84	1.12	1.34	0.13	0.14	0.15	0.12	0.16	0.15

DAS- Days after sowing; DAP- Days after planting, HW- Hand weeding, incorp.- Incorporation, pre-em- Pre-emergence

Table 3. 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 gm. ha ⁻¹ pre-em+ HW 70, 100 and 140 DAP	7279	8208
W ₄ : Metribuzine 500 gm. 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, HW- Hand weeding, incorp.- Incorporation, pre-em- Pre-emergence

Table 4. Harvest index of ginger

Treatments	2014-15	2015-16
Cropping system		
I ₁ : G+C (2:1); C incorp. 40 DAS	0.91	0.91
I ₂ : G+C (3:1); C incorp. 40 DAS	0.91	0.91
I ₃ : C in between G; incorp. 40 DAS	0.92	0.92
I ₄ : C in alternate rows; incorp. 40 DAS	0.92	0.92
CD _{P=0.05}	NS	NS
SEm±	0.01	0.01
Weed management		
W ₁ : Weedy	0.90	0.90
W ₂ : HW 40, 70, 100 and 140 DAP	0.91	0.92
W ₃ : Oxadiargyl 90 gm. ha ⁻¹ pre-em+ HW 70, 100 and 140 DAP	0.92	0.92
W ₄ : Metribuzine 500 gm. ha ⁻¹ pre-em+ HW 70, 100 and 140 DAP	0.92	0.93
CD _{P=0.05}	NS	NS
CV (%)	3.30	3.59
SEm±	0.01	0.01
DAS- Days after sowing; DAP- Days after planting, HW- Hand weeding, incorp.- Incorporation, pre-em- Pre-emergence		

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