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Assessing Crop Growth Indices of *Nadia* Variety of Ginger (*Zingiberofficinale* Rosc.) under Legume Intercropping and Weed Management Practices

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Authors' contributions

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

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ABSTRACT

A study was initiated in Instruction-cum-Research Farm of Assam Agricultural University, Jorhat-13, Assam, India during 2014-15 and 2015-16. 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, a commercially grown variety of ginger in Assam was examined in the current study. A total of 16 treatment combinations were considered which comprised of 4 intercropping systems along with 4 weed management practices. Amongst the legume intercropping, 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 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 g 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.

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Keywords: Intercropping; weed management; legume; cowpea; ginger; metribuzin; pre-emergence.

1. INTRODUCTION

Ginger is one of the most valued commercial crops, due to its high value of return received from it. 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 [1]. As per the matrix available in Statistia (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 percent to the country's ginger production.

Being a widely spaced and long duration crop, ginger faces tremendous challenges against different pest at different growth stages. One major challenge is weed competition at its critical period of growth due to ample space availability at the early growth stage. If crop weed competition exceeds beyond 60 days after planting, it might lead to a yield loss of around 42.3% [2]. On the contrary, due to the widely spaced nature of ginger, growers also have an advantage of growing some selected short duration leguminous crop which will in turn fetch some additional benefit in terms of monetary return, soil enhancement due to nitrogen fixation and also escape the critical period of crop weed competition.

Depending on the varietal importance, ginger growers select different cultivars in different region. One such important commercially grown ginger variety in Assam is Nadia [3]. This variety is majorly cultivated for its high yield fetching ability, with a crude fiber content of 5.9%, dry matter content of 22.3% and essential oil content of 1.5% [4]. 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 initiated 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.

2. MATERIALS AND METHODS

2.1 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 m^2 subplots, comprising of 3 replications and 16 treatment combinations totaling to 48 numbers of sub-plots, accounting for a net area of 960 m^2 and gross area 1482 m^2. The experimental design was Randomized Block Design (RBD). Farm yard manure @ 10 t ha^{-1} was applied during the time of bed preparation and recommended dose of N:P_2O_5:K_2O @ 75:50:50 kg ha^{-1} in the form of urea (46% N), single super phosphate (16% P_2O_5) and muriate of potash (60% K_2O) were applied.

2.2 Treatment Details

There were total 16 treatment combinations comprising of 4 Legume Intercropping System *viz.,* I_1: Ginger + Cowpea (2:1); Cowpea incorporated at 40 DAS, I_2: Ginger + Cowpea (3:1); Cowpea incorporated at 40 DAS, I_3: Cowpea in between rows of Ginger and incorporated at 40 DAS, I_4: Cowpea in between alternate rows of Ginger and incorporated at 40 DAS and 4 Weed Management Practices *viz.*, W_1: Weedy (Control), W_2: Hand weeding at 40, 70, 100 and 140 DAP, W_3: Pre-emergence application of Oxadiargyl 90 g ai ha^{-1} + hand weeding at 70, 100 and 140 DAP and W_4: Pre-emergence application of Metribuzin 500 g ai ha^{-1} + hand weeding at 70, 100 and 140 DAP.

2.3 Planting Materials

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. 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 40^{th} day after sowing. Ginger planting and Cowpea sowing was completed on the same.

2.4 Herbicide Application and Inter-Cultural Operations

Pre-emergence herbicides were applied with a spray volume of 500 L ha^{-1}on the 3^{rd}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.

2.5 Harvesting

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.

2.6 Estimations

2.6.1 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 [5].

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

2.6.2 Crop growth rate (g m^{-2} day^{-1}) of ginger at different days after planting

It was calculated using the formula of Watson [6] and expressed as g m^{-2} day^{-1}.

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

Where, W_1 = Dry weight of the crop at first harvest (g), W_2 = Dry weight of the crop at second harvest (g), 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).

2.6.3 Absolute growth rate (g $plant^{-1}$ day^{-1}) of ginger at different days after planting

It was calculated using the formula of Watson [6] and expressed as g m^{-2} day^{-1}.

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

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

2.6.4 Harvest index of ginger

Harvest index was calculated for ginger at the time of harvest by using the following formula [5].

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

3. RESULT AND DISCUSSION

3.1 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 Metribuzin 500 g ha^{-1} pre-em + HW 70, 100 and 140 DAP recorded higher LAI of 5.07, 21.80 and 29.76 in 2014-15 and 6.50, 24.63 and 33.48 in2015-16 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 turmeric with Metribuzin were also reported by Shalini et al. [7].

3.2 Crop Growth Rate (g m^{-2} day^{-1}) and Absolute Growth Rate (g m^{-2} day^{-1}) of Ginger at Different days after Planting

Legume inter cropping system of Cowpea in between Ginger; incorporated at 40 DAS recorded the highest CGR of 32.32, 40.60 and 36.84 g 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 [6]. Thus, increased leaf area leads to increased photosynthate production helping increase in crop growth rate. This in turn had attributed towards higher rate of metabolic functions which has contributed in increased growth by virtue of better nutrient availability and its uptake by an individual plant [8].

Pre-emergence application of Metribuzin 500 g ha^{-1} pre-em + HW 70, 100 and 140 DAP resulted significantly higher CGR of 38.69, 47.86 and 44.28 g m^{-2} day^{-1} in 2014-15 and 37.90, 50.10 and 45.80 g m^{-2} day^{-1} in 2015-16 at 130, 160 and 190 DAP, respectively. Treatment with Metribuzin 500 g 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).Weed free environment for a longer duration resulted in higher rate of photosynthate accumulation leading to increased crop growth rate and absolute growth rate under this weed management treatment. Similar, results were reported by Law-ogtoma et al. [9] on Amaranthus.

3.3 Yield (kg ha^{-1}) of Ginger Rhizome

Highest yield of 7542 and 8633 kg ha^{-1} in 2014-15 and 2015-16 respectively was recorded in the treatment of Cowpea in between Ginger; incorporated at 40 DAS. This 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. [10] reported similar findings from a study on potato.

Amongst the weed management treatments, pre-emergence application of Metribuzin 500 g 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 Metribuzin application in potato crop was reported by Singh [11] and Gill et al. [12] in turmeric.

3.4 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. [13].

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 Metribuzin 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 Metribuzin 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 result between treatments. This is in alignment with the findings of Chandra at al. [14] in wheat crop.

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 g 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 g 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 (g m^{-2} day^{-1}) and absolute growth rate (g m^{-2} day^{-1}) of ginger at different days after planting

Treatments	Crop growth rate (g m^{-2} day^{-1})						Absolute growth rate (g m^{-2} 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±	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±	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 g ha^{-1} pre-em+ HW 70, 100 and 140 DAP	7279	8208
W_4 : Metribuzine 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, 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 g ha^{-1} pre-em+ HW 70, 100 and 140 DAP	0.92	0.92
W_4 : Metribuzine 500 g 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

4. 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 accorded 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 g ha^{-1} pre-em + HW 70, 100 and 140 DAPwas significantly better in terms of ginger growth indices and rhizome yield.

DISCLAIMER

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.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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