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EFFECT OF IRRIGATION AND MULCHING ON GROWTH AND YIELD OF GINGER

M.A. Islam[1], M.A. Rahim[2] and T.M.T. Iqbal[3]

[1]Spices Research Center, BARI, Bogra; [2]BAU, Department of Horticulture, Mymensingh
[3]Department of Horticulture, HSTU, Dinajpur

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Abstract

A field experiment was conducted at the Spices Research Center, BARI, Bogra, Bangladesh during 2009-10 to determine the impact of irrigation and suitability of mulch materials on the growth and yield of ginger. The experiment was laid out in the randomized complete block design (RCBD) with three replications. The treatments comprising of two factors viz., two irrigation (I_1: irrigation in dry period and I_2: control i.e. no irrigation and three mulching material (M_0: control (no mulch) M_1: water hyacinth and M_2: rice straw). Treatment revealed that I_1: (irrigation in dry period) showed that early emergence, highest plant height, number of leaves/plant, number of tillers/plant with maximum weight of primary and secondary rhizome, highest dry matter % and weight of old mother rhizome t ha^{-1}. The highest yield of rhizome (21.19 t ha^{-1}) was obtained from I_1: (irrigation in dry period). Among the mulch treatments, the highest rhizome yield (22.51 t ha^{-1}) was obtained from M_2 (ricer straw mulch). The combined effect of I_1M_2 (irrigation in dry period with rice straw mulch) produced the highest rhizome yield (25.07 t ha^{-1}).

Introduction

Ginger (*Zingiber officinale* Rosc.) is an important spice crop in Bangladesh. It is valued for its diversified uses in various drinks, medicines and culinary purposes (Pruthi, 1998). Beside the varietal factor, the yield of ginger can be increased with the adoption of improved agronomic practices, like irrigation and suitable mulch materials. Mulch and irrigation are the two important aspects of ginger production. Generally, farmers depend on unpredicted rainfall, which results in late planting. In the early season, soil remains dry, and therefore irrigation at the early stage is needed for ginger growth. The crop is affected by weed except when mulching and adequate weed control measures are taken during the early the stage of growth. Generally, ginger is cultivated under the rainfed conditions in Bangladesh. As irrigation facilities are inadequate and early monsoon rain is not certain, conservation of residual soil moisture by artificial means is be very useful for the plants in maximizing the growth and production of the crop. Artificial mulches like water hyacinth and rice straw can be used to serve this purpose. Mulch conserves soil moisture and protects sprouting of seed materials from excessive heat and desiccation (Onwueme, 1978). Application of mulch soon after planting is beneficial for the culture of some root and tuber crops (Awal *et al.*, 1978; Jha *et al.*, and 1986). Mulched plot gives higher yield than non-mulched plot (Nick *et al.*, 1969; Mannan and Rashid, 1983). Since soil moisture becomes a limiting factor for emergence and early growth of ginger, the use of mulch may be beneficial. Irrigation and mulch play an important role to increase the yield potential of ginger. Ginger is generally cultivated in kharif season in Bangladesh. Irrigation facilities are inadequate and the early monsoon rain is also uncertain. Thus irrigation and

mulching may be the most important factors of ginger production. So, this experiment was undertaken to investigate the effects of irrigation and mulching on the growth and yield of ginger.

Materials and Methods

The experiment was conducted at the research farm of the Spices Research Centre, BARI, Bogra, during the period from April 2009 to January 2010. It has sub-tropical climate with an average annual rainfall of 237.13 mm. The soil was Tista polal tract, having a p^H value of 5.8-6.6. The experiment was laid out in a randomized complete block design (RCBD) with three replications. Healthy ginger rhizome Var. BARI Ada-1 was used for planting material. Two irrigation levels viz., I_1 (irrigation in dry period: 7days before planting and 60 days after planting) and I_2 (no irrigation) were consisted as the first factor and three mulching materials viz., M_0 (control), M_1 (water hyacinth) and M_2 (rice straw) were considered as the second factor. Planting was done on the 1st April, 2009. The crop was fertilized with cowdung, urea, TSP, MP and gypsum at 5 ton, 304, 267, 233 and 111 kg ha^{-1}, respectively. Total cowdung was applied at the time of general land preparation and the entire quantity of TSP, gypsum and half of MP was applied during the final land preparation. Half of the urea was applied 50 days after planting and the remaining MP and urea were applied in two equal splits at 80 and 110 days after planting. Earthing up was done at 60, 90 and 110 days after planting. The data on different growth parameters were recorded from randomly of 10 selected plants of each plot 15 days interval at 50, 65, 80, 110, 125, 140 and 155 days after planting. Yield and yield contributing characters were collected at harvesting time. The Ist irrigation was applied 7 days before planting and the 2nd irrigation after 60 DAP (Days after planting). Irrigation was done at the level of critical point indicated by moisture meter (delta T England). Irrigation water applied twice 80 mm each time. Irrigation water was applied twice at 7 days before planting and at 60 days after planting. The discharge of water through hose pipe (Diameter 2.5 cm) was calibrated before application. The discharge of water through this pipe was 20 mm pipe per minute. The mulch materials were covering with the 4 cm thickness. Water hyacinth and rice straw mulch were placed before the rhizomes started to emerge. A second mulch was added at 60 days after planting as the first one was washed away by rain, wind and irrigation water. Rice straw and water hyacinth were applied at 2.0 and 2.5 kg/m^2; respectively. The soil samples were taken from each plot at 0-10 cm depth before each irrigation. The samples were weighed and oven dried at 100^0 C for 24 hours. The collected data were analyzed statistically and adjusted with least significance (LSD) at 5% level of probability.

Results and Discussion

Soil moisture content

Soil moisture at the field capacity of the experimental plot was 25.4%. At the beginning, application of mulch in non-irrigated or irrigated plot conserved more moisture compared to non-mulch + no-irrigation plot. At this time, rice straw mulch + no-irrigation conserved about 1.8% more moisture than water hyacinth + no-irrigation treatment. Similarly rice straw mulch + irrigation conserved about 1.14% more moisture than water hyacinth + irrigation treatment. Irrigation applied after two months of planting showed that moisture content in rice straw mulch + irrigation conserved more moisture compared to water hyacinth + irrigation and no-mulch + irrigation treatments (Table 1). At this time, rice straw mulch + irrigation conserved

about 1.01% more moisture than water hyacinth + irrigation treatment. The highest soil moisture was found in irrigation + rice straw mulch (19.35% in before planting and 8.65% in two months after planting) while the lowest moisture control treatment (17.0 %) before planting and 6.5% in two months after planting) (Table 1). The rice straw mulch possibly conserved more soil moisture and suppressed weeds (Table 1), which helped plant growth and deposition of more food materials. Similar result was also reported by Ghosh *et al.* (2007) who observed the maximum yield per plant from the plants under the paddy straw mulch. The influence of mulching treatment was found significant on the rhizome yield.

Table 1. Residual soil moisture contents of the experimental plots at 10 cm depth at the beginning and two months after planting the crop

Treatment combination	Moisture content at the beginning (%)	Moisture content after 2 month of planting (%)	Moisture at field capacity (%)
Control + No Irrigation	17.00	6.50	25.4
Water hyacinth + No Irrigation	17.80	7.10	
Rice straw + No Irrigation	18.00	8.13	
Control + Irrigation in dry period	17.22	6.85	
Water hyacinth + Irrigation in dry period	18.21	7.64	
Rice straw + Irrigation in dry period	19.35	8.65	

Plant height was significantly influenced by irrigation. The highest plant (71.66 cm) was obtained from the treatment I_1 (irrigation in dry period) and the lowest (60.45 cm) in I_2 (control) treatment at the 125 DAP (Fig. 1). The better result in I_1 may be due to conserved soil moisture that favored rapid plant growth. This finding agrees with Pawar, 1990; and Singh *et al.*, 2000. Mulch had significant influence on plant height. The tallest plant (74.29 cm) was found in the treatment M_2 (rice straw mulch) while the lowest (57.30 cm) in M_0 (control) treatment at 125 DAP (Fig.2).

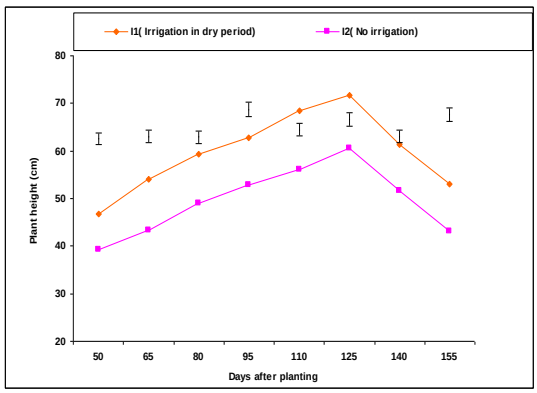

Fig. 1. Main effects of irrigation on the plant height of ginger. Vertical bars represent LSD at 5% level of probability

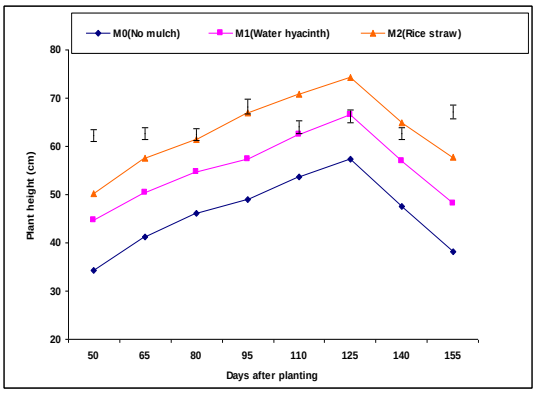

Fig. 2. Main effects of mulching on the plant height of ginger. Vertical bars represent LSD at 5% level of probability

After 125 DAP, plant height decreased gradually due to senescence of leaves. It might be due to mulching which had reduced the evaporation of soil moisture, weed growth and conserved moisture from rainfall during the early stage of plant growth. Similar result was also reported by Mohanthy *et al.* (1991), Chandra *et al.* (2001) and Ghosh *et al.* (2007).

The combined effect of irrigation and mulching on plant height was significant from 50 to 155 DAP. The tallest plant (79.76 cm) was recorded from I_1M_2 (irrigation in dry period with rice straw mulch) and the shortest plant (50.87 cm) from I_2M_0 (control) at 125 DAP (Table 4). Possible due to irrigation with rice straw mulching reduced soil temperature, conserved soil moisture, minimize the evaporation loss and enhances root growth and water use efficiency. So, plant was vigorous and rapid growth. This finding agreed with the finding of Zaman *et al.* (2002) and Mishra and Mishra (1982).

The numbers of leaves per plant were counted at different growth stages and interval of 15 days at 50, 65, 80, 95, 110, 125, 140 and 155 DAP. A significant variation was observed for numbers of leaves per plant at those stages and interval. The highest number of leaves (106.28) was recorded from I_1 (irrigation in dry period) and the lowest (88.77) in the I_2 (control) treatment at 125 DAP (Fig. 3). Irrigation increased soil moisture content by plants resulting enhanced growth of plants. This finding agrees with Pawar (1990) and Singh *et al.* (2000). In case of mulch, the maximum number of leaves (129.28) was recorded from M_2 (rice straw) while the minimum (70.55) was recorded from M_0 (control) treatment at 125 DAP (Fig. 4).

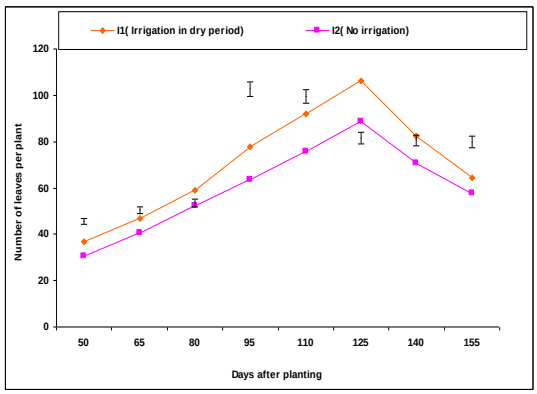

Fig. 3. Main effects of irrigation on the number of leaves per plant of ginger. Vertical bars represent LSD at 5% level of probability

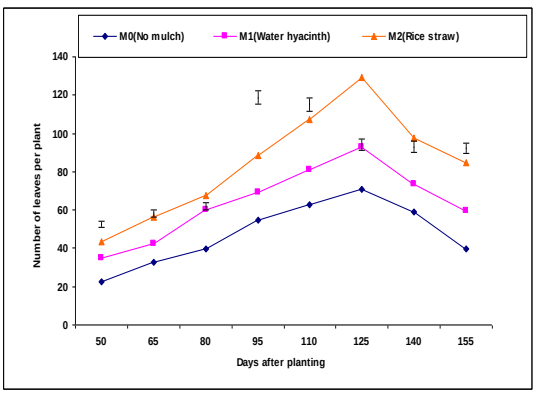

Fig.4. Main effects of mulching on the number of leaves per plant of ginger. Vertical bars represent LSD at 5% level of probability

Almost similar trend regarding number of leaves per plant was obtained by Ghosh *et al.* (2007). In case of combined effect the highest number of leaves (141.80) was counted in the I_1M_2 (irrigation in dry period with rice straw mulch) while the lowest (62.10) was obtained from I_2M_0 (control) treatment combinations at 125 DAP (Table 4). It might be due to that irrigation supplied water and mulch conserved moisture in the soil to some extend which was used by the plants to promote more number of leaves per plants Ghosh (1996) obtained higher number of leaves per plant from rice straw mulch.

The number of tillers per plant was counted at different growth stage at an interval of 15 days viz. 50, 65, 80, 95, 110, 125, 140 and 155 DAP. The highest number of tillers per plant (12.25) was obtained from I_1 treatment while the lowest number of tillers per plant (9.96) was obtained from I_2 (control) treatment at 125 DAP (Fig. 5). It might be due to soil moisture that created favorable environment to absorb nutrients resulting more number of tillers per plant. This finding agrees with those of Pawar (1990) and Singh *et al.* (2000). In case of mulch, the maximum number of tillers per plant (13.91) was found in M_2 (rice straw mulch) and the lowest

(9.23) from M_0 (control) treatment at 125 DAP (Fig. 6). Possibly mulch conserved t soil moisture in the soil to some extent which helped to produce more number of tillers per plant. Ghosh *et al.* (2007) and Ghosh (1996) reported that application of straw mulch produced maximum number of tillers per plant.

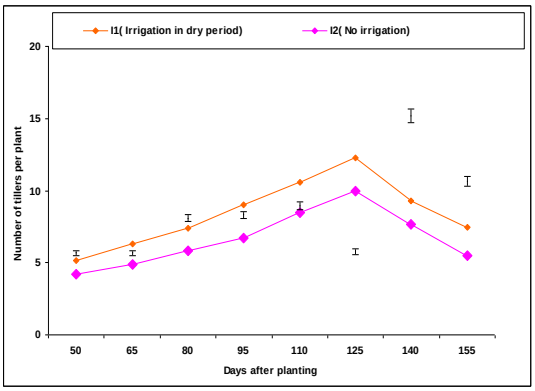

Fig.5. Main effects of irrigation on the number of tillers per plant of ginger. Vertical bars represent LSD at 5% level of probability

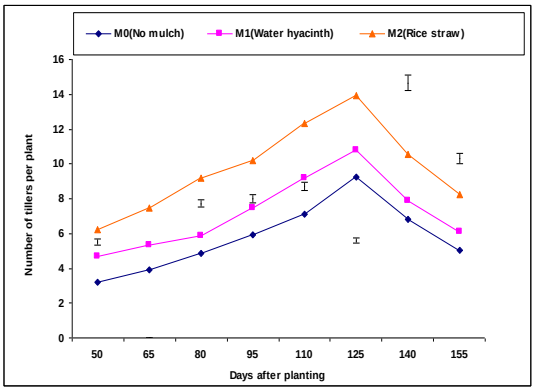

Fig.6. Main effects of mulch on the number of tillers per plant of ginger. Vertical bars represent LSD at 5% level of probability

Irrigation treatments had a significant effect on 80% emergence of seed rhizome (Table 2). The I_1 treatment (irrigation in dry period) required the minimum time (27 days) to complete 80% emergence while it was maximum (45.33 days) in I_2 (control) treatment. Similar result was also reported by Pawar, 1990 and Singh *et al.*, 2000. The weight of primary and secondary rhizome varied significantly due to irrigation, mulching and their combination. Different irrigation treatments had significant effect on the weight of primary and secondary rhizome per plant. The I_1 (irrigation in dry period) treatment showed the highest yield/plant (268.07 g and 60.80 g) of primary and secondary rhizome respectively. The lowest yield (215.81 g and 51.30 g) primary and secondary rhizome/plant was recorded from I_2 (control) treatment respectively (Table 2). This might be due to suitable soil moisture which enhanced rapid growth using the initial reserve food material. Different mulching treatments had significant effect on the weight of primary and secondary rhizome per plant. The maximum weight of primary rhizome (281.85 g)/plant was found from M_2 (rice straw mulch) and the lowest (197.17 g)/plant was obtained from M_0 (control) treatment (Table 3). Similar trend of result was obtained in case of secondary rhizome per plant where the maximum weight of secondary rhizome per plant was found from M_2 (68.44 g)/plant and the lowest from M_0 (45.89 g) /plant (Table 3). The maximum weight of primary and secondary rhizome per plant in M_2 (rice straw mulch) might be due to more soil moisture conserved by this treatment. The weight of primary and secondary rhizome significantly increased due to combined effect of mulching and irrigation treatment. The maximum weight of primary rhizome (308.94 g)/plant was recorded from I_1M_2 (irrigation in dry period with rice straw mulch) while the lowest (169.33 g) /plant was obtained from I_2M_0 (control) treatment combination (Table 4). The Maximum weight of secondary rhizome (75.0g)/plant was recorded from I_1M_2 (irrigation in dry period + rice straw mulch) while the lowest (45.00 g) /plant was obtained from I_2M_0 (control) treatment combination (Table 4). Irrigation + rice straw mulch applied plot showed vigorous plants compared to water hyacinth + irrigation and control treatment, which helped in greater deposition accumulation of assimilates

to the primary and secondary rhizomes. As a consequence it produced maximum weight of primary and secondary rhizome per plant.

The dry matter of rhizome varied significantly due to irrigation, mulching and their combined effects. The maximum dry matter of rhizome 23.38% and 23.82% was found from I_1 (irrigation in dry period) and M_2 (rice straw mulch), respectively and the minimum 21.50% and 21.00% was from I_2 (control) and M_0 (control), respectively (Table 2 & 3). In respect of combined effect of irrigation and mulching, it was observed that I_1M_2 (irrigation in dry period with rice straw mulch) produced the highest (24.63%) dry matter of rhizome. It might be due to higher vegetative growth and more accumulation of photosynthates. I_2M_0 (control) gave the lowest (20%) dry matter of rhizome (Table 4).

Weight of old mother rhizome was significantly influenced by irrigation, mulching and their combination. The maximum (2.55 t ha^{-1} and 2.63 t ha^{-1}) old mother rhizome was recorded from I_1 (irrigation in dry period) and M_2 (rice straw mulch) treatment, respectively. This finding is similar to Ghosh (1996) that reported the highest weight of old mother rhizomes was obtained from the rice straw mulch treatment. It might be happened due to the fact that the I_1 treatment and M_2 rice straw mulch conserved more soil moisture which caused more weight of old mother rhizomes. The minimum weight was (1.88 t ha^{-1} and 1.80 t ha^{-1}) from I_2 (control) and M_0 (control), treatment respectively (Table 2 & 3). The combined effect of irrigation and mulching significantly influenced the weight of old mother rhizomes. The highest weight (3.0 t ha^{-1}) was obtained from the I_1M_2 and the lowest (1.5 t ha^{-1}) was obtained from the I_2M_0 (control) treatment combination (Table 4).

Significant difference in yield (t ha^{-1}) was observed by the effect of irrigation, mulching and their combination. The maximum yield of 198.74 g/plant, 12.72 kg /plot and 21.19 t ha^{-1} were obtained from I_1 (irrigation in dry period) treatment respectively and the lowest 158.15 g/plant 10.12 kg/plot and 16.87 t ha^{-1} recorded from I_2 (control) treatment (Table 2). The irrigation treatment (I_1) possibly produced more number of leaves per plant, which helped in higher photosynthates and ultimately resulted accumulation of more food material. This finding agrees with the findings of Pawar (1990) and Singh *et al.* (2000) who stated that the adequate irrigation increased rhizome yield per hectare.

Beside this, highest yield (211.05 g/plant) was found from M_2 treatment (rice straw mulch) and the lowest (153.61 g/plant) from M_0 (control) treatment (Table 3). The rice straw mulch possibly conserved more soil moisture and suppressed weeds (Table 1), which helped plant growth and deposition of more food materials. Similar result was also reported by Ghosh *et al.* (2007) who observed the maximum yield per plant from the plants under the paddy straw mulch. The influence of mulching treatment was found significant on the rhizome yield. The height rhizome yield (13.50 kg/plot) was recorded from M_2 (rice straw mulch) while the lowest yield (9.83 kg/plot) was found from M_0 (control) treatment. Similarly different mulching treatments showed significant effect on the rhizome yield t ha^{-1} of ginger. The maximum rhizome yield (22.51 t ha^{-1}) was found from M_2 treatment and the lowest (16.38 t ha^{-1}) from M_0 treatment (Table 3). It might be due to rice straw mulch conserved more soil moisture (Table 1) and suppressed weeds, which helped produce more number of leaves per plant, enhanced plant growth, deposited of more food material and finally gave more yield. Similar results were also found by Mishra and Mishra (1982), Ghosh (1996), and Ghosh *et al.*, 2007). The combined effect irrigation and mulching was found significant on the rhizome yield per plot and yield per hectare. The maximum rhizome yield (15.04 kg/plot) was recorded from I_1M_2 and the minimum (8.86 kg/plot) was found from I_2M_0 treatment (Table 4). Similarly the maximum yield of rhizome (25.07 t ha^{-1}) was obtained from I_1M_2 while the lowest (14.76 t ha^{-1}) was

found from I_2M_0 treatment combination (Table 4). The treatment I_1M_2 was observed better as irrigation and straw mulch conserved more soil moisture and suppressed weed growth. So, crop growth was better with the maximum number of leaves per plant, which helped in photosynthesis and ultimately resulted maximum rhizome yield per hectare. This finding was in agreement with those of Pawar (1990) and Singh *et al.* (2000). They reported that irrigation with mulching produced the highest yield of rhizomes per hectare.

Table 2. Effect of irrigation on the growth and yield of ginger

Treatment	Emergence (%) at DAP				Wt. of primary rhizomes/plant (g)	Wt. of secondary rhizomes/ plant (g)	Dry matter (%)	Weight of old mother rhizomes (t ha^{-1})	Rhizome yield (t ha^{-1})
	20	40	60	80					
I_1	18.00	21.33	23.33	27.00	268.07	60.80	23.38	2.55	21.19
I_2	24.33	30.00	36.67	45.33	215.81	51.30	21.50	1.88	16.87
LSD $_{(0.05)}$	3.31	3.74	4.59	3.81	5.08	5.95	0.57	0.39	3.87
CV (%)	10.53	9.83	10.31	7.10	1.42	7.17	1.73	11.89	13.75

I_1: irrigation in dry period, I_2: no irrigation, DAP: Days after planting

Table 3. Effect of mulching on the growth and yield of ginger

Treatment	Emergence (%) at DAP				Wt. of primary rhizomes/plant (g)	Wt. of secondary rhizomes/ plant (g)	Dry matter (%)	Weight of old mother rhizomes (t ha^{-1})	Rhizome yield (t ha^{-1})
	20	40	60	80					
M_0	25.5	31.00	35.00	39.50	197.17	45.89	21.00	1.80	16.38
M_1	20.5	25.00	29.50	36.00	246.80	53.82	22.50	2.23	18.20
M_2	17.5	21.00	25.5	33.00	281.85	68.44	23.82	2.63	22.51
LSD $_{(0.05)}$	2.87	3.25	3.98	3.31	4.41	5.17	0. 50	0.34	3.37
CV (%)	10.53	9.83	10.31	7.10	1.42	7.17	1.73	11.89	13.75

M_0: no mulch, M_1: water hyacinth, M_2: rice straw, DAP: Days after planting

On the other hand mulch had significant effect on 80% emergence. It was observed that the plants under M_2 (rice straw mulch) took the minimum (33.0 days) to complete 80% emergence while it was maximum (39.5 days) in case of M_0 (control) treatment (Table 3). Mulch conserved more soil moisture which enhanced quicker emergence than control treatment. This finding agrees with the finding of Kumar *et al.* (1973) who observed that mulching enhanced early emergence. Different mulching treatments had significant effect on the weight of primary and secondary rhizome per plant. The maximum weight of primary rhizome (281.85 g)/plant was found from M_2 (rice straw mulch) and the lowest (197.17 g)/plant was obtained from M_0 (control) treatment (Table 3). Similar trend of result was obtained in case of secondary rhizome per plant where the maximum weight of secondary rhizome per plant was found from M_2 (68.44 g)/plant and the lowest from M_0 (45.89 g) /plant (Table 3). Beside this, highest yield (211.05 g/plant) was found from M_2 treatment (rice straw mulch) and the lowest (153.61 g/plant) from M_0 (control) treatment (Table 3). The height rhizome yield (13.50 kg/plot) was recorded from M_2 (rice straw mulch) while the lowest yield (9.83 kg/plot) was found from M_0 (control) treatment. Similarly different mulching treatments showed significant effect on the

rhizome yield t ha^{-1} of ginger. The maximum rhizome yield (22.51 t ha^{-1}) was found from M_2 treatment and the lowest (16.38 t ha^{-1}) from M_0 treatment (Table 3). It might be due to rice straw mulch conserved more soil moisture and suppressed weeds, which helped produce more number of leaves per plant, enhanced plant growth, deposited of more food material and finally gave more yield. Similar results were also found by Mishra and Mishra (1982), Ghosh (1996), and Ghosh *et al.*, 2007).

Table 4. Combined effect of irrigation and mulching on the growth and yield of ginger

Treatment	Plant height (cm) at different days after planting								No. of leaves/plant at different days after planting							
	50	65	80	95	110	125	140	155	50	65	80	95	110	125	140	155
I_1M_0	37.93	45.40	50.33	53.00	60.93	63.73	51.80	45.93	24.77	34.80	41.63	59.53	68.53	79.00	62.80	43.17
I_1M_1	48.62	53.81	59.65	63.43	68.27	71.49	61.73	51.87	36.22	42.74	63.87	75.23	83.92	98.05	74.62	58.53
I_1M_2	53.77	63.09	67.77	71.87	76.07	79.76	70.47	61.17	49.49	62.55	71.17	98.68	122.95	141.80	110.14	92.00
I_2M_0	30.66	37.25	41.95	44.93	46.30	50.87	43.30	30.57	20.53	30.40	37.27	49.40	57,33	62.10	54.88	35.80
I_2M_1	40.60	46.87	49.81	51.43	56.44	61.67	52.06	44.42	33.60	41.70	56.17	63.00	78.07	87.43	72.33	60.38
I_2M_2	46.72	51.89	55.30	62.14	65.72	68.82	59.28	54.38	37.02	49.89	63.60	78.04	91.73	116.76	85.27	77.33
CV (%)	8.89	7.78	7.11	7.57	6.42	6.35	6.86	8.91	6.10	5.18	4.32	6.53	5.34	3.76	4.72	5.87

Table 4. (Contd.)

Treatment	No. of tillers/plant at different days after planting								Emergence (%)				Wt. of primary rhizomes/ plant (g)	Wt. of secondary rhizomes/ plant (g)	Dry matter (%)	Weight of old mother rhizomes (t ha^{-1})	Rhizome yield (t ha^{-1})
	50	65	80	95	110	125	140	155	20	40	60	80					
I_1M_0	3.53	4.14	5.02	6.47	7.73	10.13	7.43	5.73	21.0	24.0	26.0	30.0	225.00	46.78	22.00	2.10	18.00
I_1M_1	4.91	6.18	6.37	8.57	9.86	11.84	8.28	7.01	18.0	22.0	24.0	27.0	270.26	60.62	23.5	2.56	20.51
I_1M_2	7.06	8.60	10.88	12.10	14.17	15.97	11.98	9.59	15.0	18.0	20.0	24.0	308.94	75.00	24.63	3.00	25.07
I_2M_0	2.83	3.67	4.68	5.37	6.47	8.33	6.23	4.30	30.0	38.0	44.0	49.0	169.33	45.00	20.0	1.50	14.76
I_2M_1	4.43	4.50	5.33	6.40	8.47	9.69	7.53	5.19	23.0	28.0	35.0	45.0	223.34	47.02	21.50	1.90	15.89
I_2M_2	5.37	6.37	7.51	8.30	10.50	11.85	9.17	6.89	20.0	24.0	31.0	42.0	254.75	61.87	23.0	2.25	19.95
LSD (0.05)	0.87	0.87	1.23	1.27	1.38	0.89	2.34	1.64	4.06	4.59	5.63	4.67	6.23	7.31	0.71	0.48	4.76
CV (%)	10.21	8.61	10.23	8.88	7.97	4.31	15.22	13.98	10.53	9.83	10.31	7.10	1.42	7.17	1.73	11.89	13.75

I_1: irrigation in dry period, I_2: no irrigation, M_0: no mulch, M_1: water hyacinth mulch, M_2: rice straw mulch, DAP: Days after planting

In case of combined effect the, maximum (49.0 days) were recorded in I_2M_0 (control) treatment while the minimum (24.0 days) were required in I_1M_2 (irrigation in dry period with rice straw mulch) treatment combination (Table 4). It might be due to the fact that irrigation and mulching conserved soil moisture, reduced soil temperature, minimized the evaporation loss, and enhanced root growth. This finding agrees with those of Chowdhury and Prihar (1974), Pawar (1990) and Ghosh *et al.* (2007). The combined effect of irrigation and mulching on plant height was significant from 50 to 155 DAP. The tallest plant (79.76 cm) was recorded from I_1M_2 (irrigation in dry period with rice straw mulch) and the shortest plant (50.87 cm) from I_2M_0 (control) at 125 DAP (Table 4). It might be possible due to irrigation with rice straw mulching reduced soil temperature, conserved soil moisture, minimize the evaporation loss and enhances root growth and water use efficiency. So, plant was vigorous and rapid growth. This finding agreed with the finding of Zaman *et al.* (2002) and Mishra and Mishra (1982). Almost similar trend regarding number of leaves per plant was obtained by Ghosh *et al.* (2007). In case of combined effect the highest number of leaves (141.80) was counted in the I_1M_2 (irrigation in

dry period with rice straw mulch) while the lowest (62.10) was obtained from I_2M_0 (control) treatment combinations at 125 DAP (Table 4). It might be due to that irrigation supplied water and mulch conserved moisture in the soil to some extend which was used by the plants to promote more number of leaves per plants Ghosh (1996) obtained higher number of leaves per plant from rice straw mulch. The maximum weight of primary and secondary rhizome per plant in M_2 (rice straw mulch) might be due to more soil moisture conserved by this treatment. The weight of primary and secondary rhizome significantly increased due to combined effect of mulching and irrigation treatment. The maximum weight of primary rhizome (308.94 g)/plant was recorded from I_1M_2 (irrigation in dry period with rice straw mulch) while the lowest (169.33 g) /plant was obtained from I_2M_0 (control) treatment combination (Table 4). The Maximum weight of secondary rhizome (75.0g)/plant was recorded from I_1M_2 (irrigation in dry period + rice straw mulch) while the lowest (45.00 g)/plant was obtained from I_2M_0 (control) treatment combination (Table 4). Irrigation + rice straw mulch applied plot showed vigorous plants compared to water hyacinth + irrigation and control treatment, which helped in greater deposition accumulation of assimilates to the primary and secondary rhizomes. As a consequence it produced maximum weight of primary and secondary rhizome per plant. In respect of combined effect of irrigation and mulching, it was observed that I_1M_2 (irrigation in dry period with rice straw mulch) produced the highest (24.63%) dry matter of rhizome. It might be due to higher vegetative growth and more accumulation of photosynthates. I_2M_0 (control) gave the lowest (20%) dry matter of rhizome (Table 4). The combined effect of irrigation and mulching significantly influenced the weight of old mother rhizomes. The highest weight (3.0 t ha^{-1}) was obtained from the I_1M_2 and the lowest (1.5 t ha^{-1}) was obtained from the I_2M_0 (control) treatment combination (Table 4). The combined effect irrigation and mulching was found significant on the rhizome yield per hectare. The maximum rhizome yield (15.04 kg/plot) was recorded from I_1M_2 and the minimum (8.86 kg/plot) was found from I_2M_0 treatment (Table 4). Similarly the maximum yield of rhizome (25.07 t ha^{-1}) was obtained from I_1M_2 while the lowest (14.76 t ha^{-1}) was found from I_2M_0 treatment combination (Table 4). The treatment I_1M_2 was observed better as irrigation and straw mulch conserved more soil moisture and suppressed weed growth. So, crop growth was better with the maximum number of leaves per plant, which helped in photosynthesis and ultimately resulted in maximum rhizome yield per hectare. This finding was in agreement with those of Pawar (1990) and Singh *et al.* (2000). They reported that irrigation with mulching produced the highest yield of rhizomes per hectare. The combined effect of irrigation and mulching was significant to influence the number of tillers per plant. The highest number of tillers per plant (15.97) was counted from I_1M_2 and the lowest (8.33) from I_2M_0 (control) treatment combination at 125 DAP (Table 4). This might be due to I_1M_2 irrigation and mulch reduced soil temperature fluctuation, minimized evaporation loss, conserved soil moisture, enhanced root growth and produced more number of tillers per plant. Almost similar trend in number of tillers per plant was obtained by Ghosh (1996). Ghosh (2007) reported that plants with rice straw mulch produced maximum number of tillers per plant followed by water hyacinth.

Conclusion

The study concluded that the rhizome yield of ginger was significantly affected by the irrigation, mulching and their combined effects. The growth and yield attributes of ginger rhizome were increased when irrigation as applied irrigation in dry period (7 days before planting and 60 days after planting). Mulching also influenced the growth and yield of ginger rhizome. The rice straw mulch gave the highest yield of ginger rhizome. However, irrigation in dry period with rice

straw mulch resulted in the highest rhizome yield per unit area. Further investigation is needed in suggested for different agro-ecological region of Bangladesh in order to confirm the present findings.

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