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Biomass Production and Growth Rates at Different Phenophases of Garlic as Influenced by Natural and Synthetic Mulches

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Abstract: A field experiment was conducted to study the effect of natural and synthetic mulches on biomass distribution in various parts and growth rates at different phenophases of local and exotic garlic (*Allium sativum* L.) cultivars. Significant variations exist among the different mulches in respect of dry matter partitioning and physiological characters of garlic. The results showed that Biomass production of leaf, root and pseudostem increased up to 105 days after planting (DAP) and thereafter decreased gradually at the approach of maturity. Total dry matter (TDM) also had a similar trend. Leaf area index (LAI) increased up to 90 DAP and then decreased gradually. CGR increased gradually with the advancement of crop growth. However, RGR from its highest value at early growth stage continued to decrease with crop age. The results indicated that among the natural mulches, water hyacinth mulch produced the plants with higher LAI, TDM and CGR but lower RGR. Transparent polyethylene mulch had a negative effect on growth of garlic. However, it had relatively higher RGR except 75 DAP and the non-irrigated control had the highest RGR. The exotic cultivar had higher biomass production, LAI, TDM and CGR but lower RGR in comparison to the local one.

Key words: Dry matter partitioning, growth rate, management practice, microclimatic manipulation, mulching

Introduction

Garlic (*Allium sativum* L.) is one of the important and widely cultivated spice crop used for food as well as medicinal purposes. It has been valued for its thrombotic, lipid-lowering, cardiovascular and anticancer effects (Agarwal, 1996). Popularity of this crop has recently increased world wide because of the many health benefits of garlic consumption. Garlic is cultivated in the mild, dry and short winter in Bangladesh. It is known to be thermo-photo-sensitive crop, its vegetative growth and bulb development are greatly influenced by growing environment (Jones and Mann, 1963; Rahim and Fordham, 1988). Manipulation of growing environment by cultural practices has the potentiality to improve yield of any crop. Mulching is one of the good cultural practices for the favourable manipulation of microclimate for the improvement of garlic yield.

Mulching has been reported to conserve soil moisture (Adetunji, 1990; Bristow and Abrecht, 1989; Gajri *et al.*, 1994; Zaman and Mallick, 1991) by protecting the plants from excess transpiration and direct evaporation from soil thus reduces the irrigation requirements (Amal *et al.*, 1990; Vanderwerken and Wilcox, 1988) decrease soil temperature (Adetunji, 1990; Bristow and Abrecht, 1989; Gajri *et al.*, 1994), runoff and soil erosion (Sur *et al.*, 1992). Mulches help check weed growth and improve the soil structure and fertility by trapping nutrient-rich and wind-borne dust (Geiger *et al.*, 1992).

Most arable lands of Bangladesh suffer from inadequate soil moisture particularly during dry winter season and exploit the moisture in soil from seasonal precipitation in rainy season or flood water. Garlic cultivation during this dry winter season is very difficult. Because, irrigation facility is not available for the minor crops like garlic. As a result, garlic suffers from lack of adequate soil moisture leading to poor yield compared to the surrounding countries. Thus, mulching could solve the problem of scanty soil moisture to some extent in winter conserving the moisture.

Water hyacinth, ash, rice husk, saw dust etc. are natural mulches that are plentiful, low cost and can be obtained easily and have been used in many crops by the scientists. While others used synthetic mulches like transparent and colored polyethylene. As regards the crop yield response to mulching effects, results are variable. Straw mulch has been reported to increase yields of sorghum (Bhaskar, 1985), decrease castor bean yield and have no effect on pearl millet (Venkateswarlu *et al.*, 1986). Polyethylene mulch increased yield of onion (Suh and Kim, 1991). Adetunji (1994) reported that with the exception of sawdust mulch, both natural and synthetic mulches significantly enhanced vegetative growth and bulb yields of onion. In spite of sufficient research on other crops, reports on mulching in garlic are limited. This study reported both natural and synthetic mulches to improve yield and yield contributing traits in garlic (Haque *et al.*, submitted for publication). The objective of this study was to observe effectiveness of natural and synthetic mulching materials on dry matter partitioning and growth attributes of local and exotic cultivars of garlic.

Materials and Method

The experiment was conducted at the field laboratory of the Department of Crop Botany, Bangladesh Agricultural University, during the period from 14th Nov., 2000 to 25th Mar., 2001. A local and an exotic cultivar of garlic were used in this study. The land was at opened by a tractor. It was then thoroughly prepared by plowing and cross plowing with power tiller followed by laddering. The clods were broken into small pieces and the surface was leveled until the desired tilth was obtained. All the weeds, their rhizomes and stubbles were collected and removed from the plots.

Well-decomposed cow dung (10 t ha^{-1}), Urea (120 kg ha^{-1}), Triple superphosphate (TSP) (90 kg ha^{-1}) and Muriate of potash (MP) (180 kg ha^{-1}) were applied to the field during final land preparation and thoroughly mixed with soil. Five different mulches (dried water hyacinth, black and transparent polyethylene, saw dust and rice husk) and two control treatments (non-irrigated control and irrigated control) comprised the study. The two-factor experiment was laid out in randomized complete block design (RCBD) with 3 replications.

The entire experimental plot was divided into 3 blocks, each of which then divided into 14 unit plots. The size of the unit plot was 1.5x1.5 m^2. Two adjacent unit plots and blocks were separated by 0.5 and 1.0 m, respectively. The treatment combinations were distributed randomly among the unit plots of each block.

The cloves for planting were selected from uniform healthy bulbs of garlic. One hundred and fifty cloves were planted in each unit plot maintaining a spacing of 15x10 cm. The cloves were planted at about 4 cm depth of soil. Mulching with water hyacinth, rice husk and saw dust was done immediately after planting. Transparent and black polyethylene sheets with small holes, which were made previously maintaining proper spacing were spread over the plot so that the plantlets could emerge easily through the holes. Then the cloves were planted singly through the holes in the soil at required depth with a pointed stick. Irrigation was done by water cane in irrigated control plots. While the other control plots were kept non-irrigated. Frequency of irrigation was dependent upon the moisture status of the soil.

Data were collected from five randomly selected plants at an interval of 15 days starting from 30 days after planting till the final harvest. The selected plants of each plot were uprooted carefully ensuring maximum root extraction and they were carried to the laboratory in labelled polyethylene bags preventing transpiration and respiration losses. Then the harvested plants were washed in running tap water to remove soil and blotted with blotting paper to remove the adhering water on them. The plants were separated into leaves, pseudo-stems and roots. Total leaf area of individual sample was measured by an electronic leaf area meter (LI 3000, USA). The components were oven dried at 80 ± 2°C for 48 h to record constant dry weights. Total dry matter (TDM) was determined by accumulating the dry weight of each portion of the plant. The growth parameters like leaf area index (LAI), crop growth rate (CGR) and relative growth rate (RGR) were computed from the above data using the following formula (Hunt, 1978).

$$LAI = \frac{LA}{P}$$

$$CGR = \frac{1}{P} \frac{W_2 - W_1}{T_2 - T_1} \text{ mg m}^{-2} \text{ d}^{-1}$$

TDM= (Stem + Leaf + root + bulb) g/plant

$$RGR = \frac{1}{W_1} \frac{W_2 - W_1}{T_2 - T_1} \text{ mg g}^{-1} \text{ d}^{-1}$$

Where, LA= total leaf area
W_1= total dry weight at time T_1,
W_2= total dry weight at time T_2,
P= ground area
LA_1= Total leaf area at time T_1
LA_2= Total leaf area at time T_2

The collected data on different parameters under study were statistically analyzed. The pair comparisons were made by LSD test at 5 and 1% levels of probability. The significance of the difference between the pair of means was evaluated by Duncan's multiple range test (DMRT) using MSTAT-C programme in computer.

Results and Discussion

Dry weight of leaves plant^{-1}: The effect of different mulches on the dry weight of leaves was significant at all growth stages (Table 1). Dry weight of leaves gradually increased from 30 DAP until 105 DAP followed by a slight

Table 1: Effect of different mulches on leave dry weight at different phenophases of garlic

	Dry weight of leaves (g plant^{-1})							
Treatments	30 DAP	45 DAP	60 DAP	75 DAP	90 DAP	105 DAP	120 DAP	130 DAP
M_1	0.20a	0.38a	0.75a	1.42a	2.22a	2.94a	2.51a	2.26a
M_2	0.18ab	0.35ab	0.71ab	1.37b	2.16b	2.79a	2.25b	2.01b
M_3	0.08d	0.15e	0.34e	0.59e	0.88g	0.95f	0.54e	0.37f
M_4	0.16bc	0.31bcd	0.65bcd	1.27c	2.04d	2.12c	1.87c	1.55d
M_5	0.17abc	0.33abc	0.69abc	1.32bc	2.10c	2.43b	2.09b	1.80c
M_6	0.11c	0.26d	0.59d	1.16d	1.90f	1.96c	0.71e	0.47ef
M_7	0.14c	0.28cd	0.62cd	1.21d	1.97e	2.01c	0.93d	0.60e

Values with different letters within a column differ significantly at 5% level of probability (DMRT), M_1 = Dried water hyacinth, M_2 = Black polyethylene, M_3 = Transparent polyethylene, M_4 = Saw dust, M_5 = Rice husk, M_6 = Non-irrigated control, M_7 = Irrigated control

Table 2: Differential leaf dry weight in two cultivars of garlic at various stages of plant growth

	Dry weight of leaves (g plant^{-1})							
Cultivars	30 DAP	45 DAP	60 DAP	75 DAP	90 DAP	105 DAP	120 DAP	130 DAP
V_1	0.14b	0.26b	0.56b	1.12b	1.82b	2.09b	1.42b	1.16b
V_2	0.16a	0.32a	0.67a	1.26a	1.97a	2.25a	1.70a	1.43a

V_1 = Local cultivar, V_2 = Exotic cultivar, Significant at 1% level of probability

Table 3: Pseudo-stem dry weight of garlic plant as influenced by different mulches

	Dry weight of pseudo-stem (g plant^{-1})							
Treatments	30 DAP	45 DAP	60 DAP	75 DAP	90 DAP	105 DAP	120 DAP	130 DAP
M_1	0.07a	0.24a	0.62a	1.29a	2.24a	2.69a	2.39a	2.07a
M_2	0.06a	0.22ab	0.59a	1.24ab	2.17b	2.29b	2.24a	1.93b
M_3	0.01a	0.08e	0.28b	0.40f	0.79g	0.70e	0.63e	0.51f
M_4	0.04a	0.18bcd	0.47a	1.14cd	2.05d	1.81c	1.32c	1.10d
M_5	0.05a	0.20abc	0.55a	1.19bc	2.11c	2.08bc	1.90b	1.62c
M_6	0.03a	0.15d	0.49a	1.04e	1.94f	0.99e	0.82d	0.56f
M_7	0.03a	0.17cd	0.50a	1.09de	2.00e	1.40d	0.95d	0.80e

Table 4: Comparative pseudo-stem dry weight of two garlic cultivars at different days after planting

	Dry weight of pseudo-stem (g plant^{-1})							
Cultivars	30 DAP	45 DAP	60 DAP	75 DAP	90 DAP	105 DAP	120 DAP	130 DAP
V_1	0.039b	0.149b	0.471b	0.99b	1.83b	1.56b	1.36b	1.15b
V_2	0.045a	0.202a	0.522a	1.13a	1.97a	1.86a	1.56a	1.31a

Table 5: Effect of different mulches on root biomass at different phenophases of garlic

	Dry weight of root (g plant^{-1})							
Treatments	30 DAP	45 DAP	60 DAP	75 DAP	90 DAP	105 DAP	120 DAP	130 DAP
M_1	0.016a	0.045a	0.080a	0.22a	0.38a	0.41a	0.39a	0.36a
M_2	0.013a	0.040a	0.062ab	0.18ab	0.32b	0.38b	0.36b	0.32b
M_3	0.005a	0.019a	0.019be	0.03e	0.08f	0.26g	0.23f	0.20g
M_4	0.008a	0.027a	0.049ab	0.10cd	0.20d	0.33d	0.32d	0.29d
M_5	0.010a	0.033a	0.056ab	0.15bc	0.26c	0.35c	0.33c	0.31c
M_6	0.005a	0.019a	0.035ab	0.06de	0.13ef	0.28f	0.27e	0.23f
M_7	0.007a	0.023a	0.044ab	0.08de	0.17d	0.31e	0.26e	0.35e

Table 6: Effect of cultivars on dry weight of root in garlic plant at different days after planting

	Dry weight of root (g plant^{-1})							
Cultivars	30 DAP	45 DAP	60 DAP	75 DAP	90 DAP	105 DAP	120 DAP	130 DAP
V_1	0.009b	0.030b	0.044b	0.103b	0.199b	0.330	0.305	0.273b
V_2	0.010a	0.030a	0.055a	0.134a	0.236a	0.339	0.313	0.286a

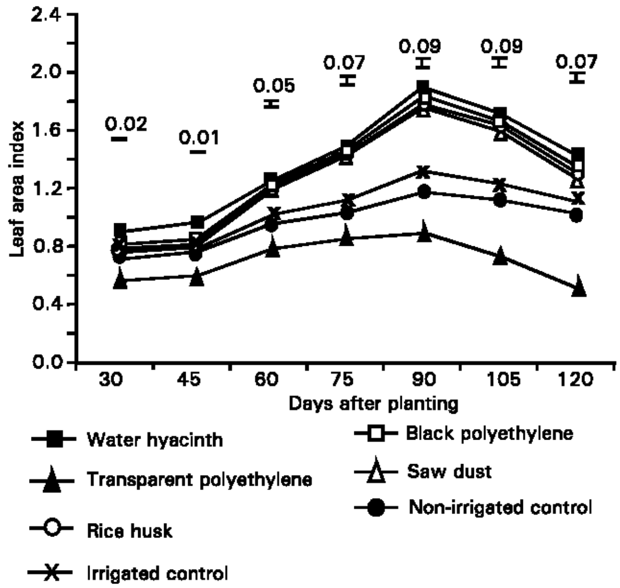

Fig. 1: Effect of different mulches on crop growth rate. Vertical bars represent LSD 5% level

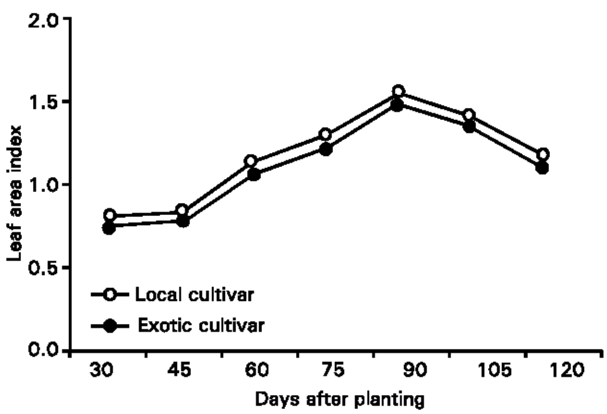

Fig. 2: Effect of cultivars on leaf area index. Significant at 1% level

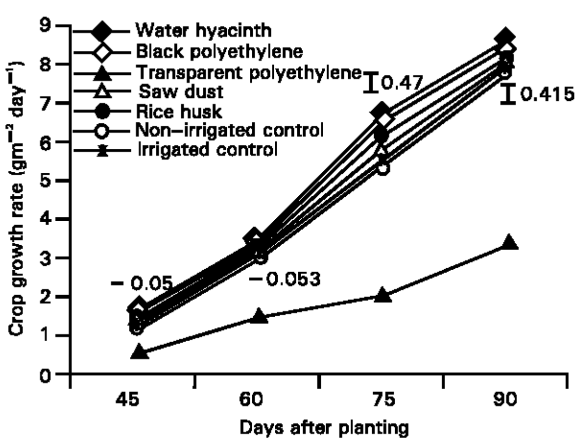

Fig. 3: Effect of different mulches on crop growth rate. Vertical bars represent LSD 5% level

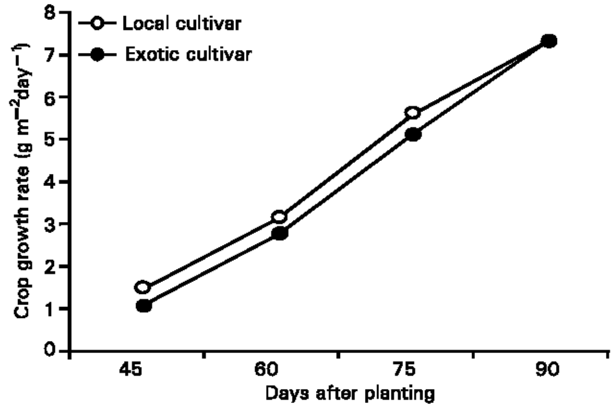

Fig. 4: Effect of cultivars on crop growth rate. Significant at 1% level

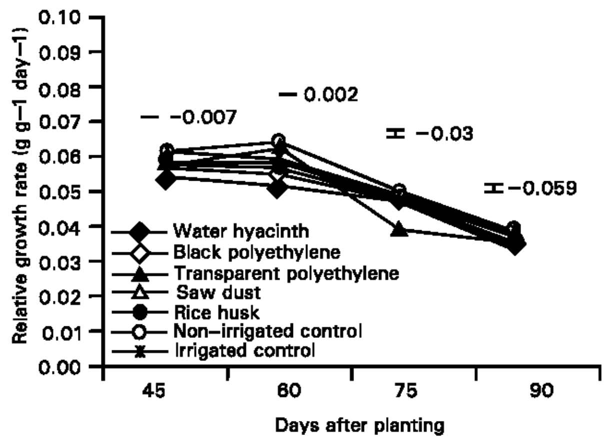

Fig. 5: Effect of different mulches on relative growth rate. Vertical bars represent LSD at 1% level

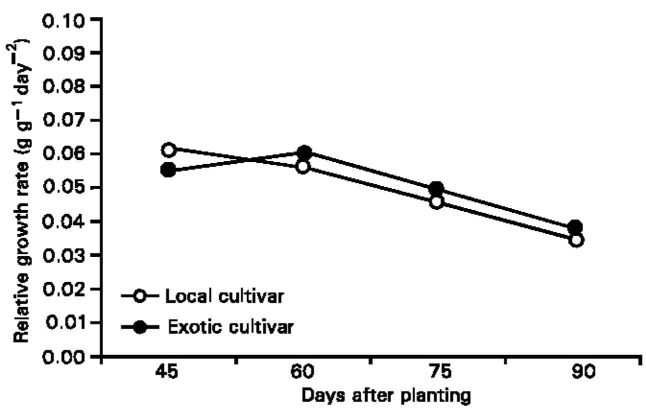

Fig. 6: Effect of cultivars on relative growth rate. Significant at 1% level

decrease at the approach of maturity in all the treatments. The plants grown under water hyacinth mulch gave maximum leaf dry weight (2.94 g) at 105 DAP followed by a statistically similar result under black polyethylene mulch. The minimum dry weight (0.95 g) of leaves was found in transparent polyethylene mulch. Two varieties of garlic differed significantly in their ability to accumulate dry matter in leaf (Table 2). The dry weight of leaves increased gradually from 30 DAP and peaked at 105 DAP and than decreased in both the cultivars. It was observed that the maximum dry weight (2.25 g) of leaves was produced by the exotic cultivar at 105 DAP. The interaction effect between different mulches and garlic cultivars was statistically significant except 45 and 105 DAP. The maximum dry weight (3.06 g) of leaves was found in M_1V_2 interaction and was followed by M_2V_2 (2.92 g) and the minimum (0.091 g) was recorded in M_3V_1. The highest dry weight of leaves was earlier reported in garlic with water hyacinth mulch (Hassan, 1999). Water hyacinth might have created a favourable microclimate for better biomass production by the plants. The decrease of leaf biomass after 105 days might be due to the redistribution of the dry matter from leaves to the developing bulb, age-depended reduction of the photosynthetic capacity and leaf senescence. The negative effect of transparent polyethylene may be attributed to the warming of the soil to temperature that might be deleterious to biomass production.

Dry weight of pseudo-stem: The variation of pseudo-stem dry weight due to different mulching treatments was estimated from 30 to 130 DAP (Table 3). The water hyacinth mulch always had the supremacy over the other treatments. It accumulated the maximum (2.69 g) amount of dry matter in pseudo-stem followed by black polyethylene (2.29 g). The minimum dry weight (0.70 g) was found with transparent polyethylene mulch treatment at 105 DAP. Two cultivars exhibited significant difference in biomass of pseudo-stem (Table 4). The exotic cultivar accumulated higher amount of dry matter in pseudo-stem than the local cultivar at all growth stages. The interaction effect of different natural and synthetic mulches and two cultivars of garlic on dry weight of pseudo-stem was significant at 45, 60, 75 and 90 DAP. The highest dry weight (2.92 g) of pseudo-stem was recorded in water hyacinth mulch followed by black polyethylene (2.61 g) mulch. The lowest dry weight (0.64 g) was observed in transparent polyethylene mulch probably due to the deleterious effect of the high temperature. The pseudo-stem biomass declined after attaining the maximum value at 105 days possibly due more diversion towards the storage organ and true stem called bulb.

Dry weight of root: Different mulches had highly significant effect on root dry matter production (Table 5). The dry weigh of roots increased gradually from 30 DAP and peaked at 105 DAP and then decreased in all the treatments. It was observed that the water hyacinth mulch had higher root biomass at all stages of growth. The maximum dry weight (0.41g) of roots was produced by this mulch followed by black polyethylene (0.38 g) at 105 DAP. The minimum dry weight (0.26 g) was found with transparent polyethylene mulch treatment at the same date. A significant varietal difference in dry weight of root plant^{-1} at different growth stages except 105 and 120 DAP was documented (Table 6). The maximum dry weight (0.339 g) of root was found in exotic cultivar and the minimum dry weight (0.330 g) was recorded in local cultivar at 105 days after planting. The dry matter accumulation in roots decreased after 105 DAP. The interaction effect between the different mulches and two cultivars of garlic on dry weight of roots was significant at 45, 60 and 75 days after planting. The maximum root weight (0.42 g) was recorded in M_1V_2 and the minimum root weight (0.24 g) was found in M_3V_1 interaction. Hassan (1999), Mia (1996) and Baten *et al.* (1995) reported similar results with water hyacinth mulch. The increased root dry weight might be due to the most favourable soil condition for root penetration, spread and growth under water hyacinth mulch while the poor root biomass under transparent polyethylene might be due to the extreme high temperature at the root zone. The root biomass declined after 105 days due to root senescence and diversion of the photosynthates towards the developing bulb.

Total dry matter: The total dry matter was recorded from 30 to 130 DAP and calculated as the sum of dry weight of leaves, pseudo-stem, roots and bulb (if any). Dry matter production steadily increased up to the maturity of the crop in all treatments (Table 7). The highest total biomass (10.00 g) was recorded in water hyacinth mulch followed by black polyethylene (8.94 g) at the final harvest (that included the dry weight of bulbs). Rice husk (7.93 g), sawdust (6.4 g), irrigated control (3.85 g) and non-irrigated control (2.97 g) were statistically identical. The lowest dry matter (1.99 g) was recorded in transparent polyethylene mulch. Two cultivars of garlic differed significantly in their ability to accumulate total biomass at all growth stages. The difference was lower in the early stages of crop growth but became pronounced at later stages (Table 8). The data revealed that exotic cultivar had superiority in accumulating dry matter over the local cultivar throughout the growth stages. The interaction effect between variety and mulch on the dry matter production was statistically significant, except at 30, 105, and 130 DAP. The highest total dry matter (5.79 g) was found in M_1V_2 and the lowest total dry matter (1.24 g) was recorded in M_3V_1 (transparent

Table 7: Effect of different mulches on total dry mater per plant in garlic

Treatments	Total dry matter (g plant^{-1})							
	30 DAP	45 DAP	60 DAP	75 DAP	90 DAP	105 DAP	120 DAP	130 DAP
M_1	0.29a	0.66a	1.43a	2.93a	4.84a	6.04a	5.30a	10.00a
M_2	0.25ab	0.61b	1.35b	2.79b	4.65b	5.63b	4.86b	8.94b
M_3	0.10e	0.23f	0.57g	1.03g	1.75g	1.63g	1.40f	1.99g
M_4	0.21bcd	0.52cd	1.23d	2.51d	4.29d	4.28d	3.51d	6.40d
M_5	0.23bc	0.56bc	1.29c	2.66c	4.47c	4.87c	4.32c	7.93c
M_6	0.17d	0.42e	1.09f	2.26f	3.97f	2.36f	1.98e	2.97f
M_7	0.18cd	0.46de	1.15e	2.38e	4.13e	2.83e	2.18e	3.85e

Values with different letters within a column differ significantly at 1% and 5% level of probability (DMRT), M_1 = Dried water hyacinth, M_2 = Black polyethylene, M_3 = Transparent polyethylene, M_4 = Saw dust, M_5 = Rice husk, M_6 = Non-irrigated control,
M_7 = Irrigated control

Table 8: Effect of cultivars on total dry matter per plant in garlic

Cultivars	Total dry matter (g plant^{-1})							
	30 DAP	45 DAP	60 DAP	75 DAP	90 DAP	105 DAP	120 DAP	130 DAP
V_1	0.19b	0.44b	1.05b	2.20b	3.85b	3.71b	3.11b	5.65b
V_2	0.22a	0.56a	1.27a	2.53a	4.18a	4.12a	3.61a	6.38a

V_1 = Local cultivar, V_2 = Exotic cultivar, Significant at 1% level

polythene x local cultivar). The maximum dry matter accumulation found in water hyacinth mulch was reported by Rahman (1999). The higher dry matter production in mulched crop might be due to more conservation of soil moisture and its greater availability and a favourable hydro-thermal condition for plant growth and biomass production.

Leaf area index: Leaf area index (LAI) was estimated from 30 until 120 DAP (Fig. 1). The different mulches had a significant effect on the leaf area index at all the growth stages. LAI increased gradually from 30 DAP, maximized at 90 DAP and thereafter decreased in all the treatments. The maximum LAI (1.88) was found in water hyacinth mulch followed by black polyethylene (1.81). However, rice husk (1.76) and sawdust (1.74) mulches gave the identical LAIs. Irrigated and non irrigated controls had different LAIs. The minimum LAI (0.88) was found in transparent polyethylene mulch. Two cultivars had differential LAIs (Fig. 2). The exotic cultivar always had higher leaf area index than the local cultivar. The interaction effect of different mulches and varieties on leaf area index was insignificant except at 30 and 45 DAP. Roy *et al.* (1990) reported a similar higher leaf area index with mulch treatment. The higher LAI under mulched crop corresponded to the higher number of leaves with the same treatment. Leaves are the photosynthetic surface area and a higher LAI up to a certain value increases yield. The crop under water hyacinth mulch having higher LAI gave higher bulb yield (Haque *et al.*, sent for publication). The decrease of the LAI values after 90 DAP is due to leaf senescence (Katiyar, 1980)

Crop growth rate (CGR): The different mulches applied in the present study significantly influenced crop growth rate at different growth stages (Fig. 3). The CGR increased with the advancement of the crop growth in all treatments. Water hyacinth treatment had the highest CGR followed by black polyethylene and rice husk mulches. The maximum CGR was recorded with water hyacinth mulch at 90 DAP and the minimum CGR was found in transparent polyethylene mulch at the same date. Between the cultivars, V_2 (exotic) had superiority in CGR over the V_1 (local) throughout the growth period (Fig. 4). The interaction effect of variety and mulch treatment on the CGR was significant at all growth stages. At 90 DAP the highest CGR (8.53 g m^{-2} day^{-1}) was observed in the M_1V_2 interaction and the lowest CGR (3.15 g m^{-2} day^{-1}) in the interaction between M_3 and V_1. This result was in agreement with that of Roy *et al.* (1990). They observed maximum CGR in potato with water hyacinth mulch. We found a gradual increase of CGR in all treatments. Similar increasing trend of CGR up to 120-150 DAP was reported in elephant foot yam (Das *et al.*, 1997).

Relative growth rate (RGR): The different mulches applied in this study significantly influenced the RGR at different growth stages. RGR was higher in the non-irrigated control plot. Lower RGR was observed in the water hyacinth treatment. RGR was higher during the early period of growth in all treatments. It gradually decreased with the advancement of crop growth (Fig. 5). The local cultivar had superiority in RGR over the exotic cultivar throughout the growth period except 45 DAP (Fig. 6). The interaction effect between variety and mulch treatments on the RGR was significant except 45 DAP. The higher RGR was estimated in non-irrigated control plants except the early crop growth stage. Significantly higher RGR was found in non-irrigated control plants of the local cultivar (M_6V_1) at 60 DAP. The lowest RGR was recorded in M_1V_2 (exotic cultivar under water hyacinth mulch). Higher RGR values were reported in mulched crop (Roy *et al*., 1990; Rahman, 1999). However, a contradictory result of higher RGR of the control plants was found in the present study. A similar decrease in RGR from its highest value at early growth with crop age was reported in elephant foot yam (Das *et al*., 1997).

In conclusion, Biomass production and growth rates can be manipulated by the application of natural and synthetic mulches in garlic. Among the mulches used in this study, dry water hyacinth mulch emerged as the most efficient in the enhancement of growth and dry matter production. Natural mulches that are abundantly available and cheaper were found better than synthetic mulches. Transparent polyethylene mulch had a negative effect on growth.

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